Return to ASch (YJ)

GEOTHERMAL RESOURCE PERMIT

APPLICATION AMENDMENT

for the

PUNA GEOTHERMAL VENTURE PROJECT

Submitted by

PUNA GEOTHERMAL VENTURE

March 1989

ENVIRONMENTAL MANAGEMENT ASSOCIATES, INC.

GEOTHERMAL RESOURCE PERMIT

APPLICATION AMENDMENT

for the

PUNA GEOTHERMAL VENTURE PROJECT

Submitted by

PUNA GEOTHERMAL VENTURE
101 Aupuni Street
Suite 1014-B
Hilo, Hawaii 96720

March 1989

Prepared by

ENVIRONMENTAL MANAGEMENT ASSOCIATES, INC.
405 South State College Boulevard, Suite 211
Brea, California 92621

PUNA GEOTHERMAL VENTURE PROJECT

GEOTHERMAL RESOURCE PERMIT APPLICATION AMENDMENT

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

TABLE OF CONTENTS
(continued)

LIST OF FIGURES

LIST OF FIGURES
(continued)

LIST OF TABLES

LIST OF APPENDICES

1. INTRODUCTION

The Puna Geothermal Venture (PGV) Project is a 25 MW (net) power plant and associated geothermal wellfield proposed for the Puna District of the Island of Hawaii. The project, located in the Kapoho section of the Kilauea Lower East Rift Geothermal Resources Subzone, will sell the generated electricity to the Hawaii Electric Light Company (HELCO) for use on the Island of Hawaii. Since the proposed project is located within an area where the designated Geothermal Resources Subzone underlies an agricultural state land use district, the project requires a Geothermal Resource Permit from the County of Hawaii.

The PGV Project is consistent with the stated objectives of providing energy self-sufficiency and diversifying Hawaii's economic base. The project will develop a new alternate energy source as well as provide additional information about the nature of the geothermal resource. These objectives are included in Hawaii's State Plan, the State Energy Functional Plan, and the County of Hawaii General Plan.

On December 10, 1986, Thermal Power Company (TPC), as then operator of the Puna Geothermal Venture partnership, submitted an application to the Hawaii County Planning Department (HCPD) for a Geothermal Resource Permit (GRP) for the PGV Project. TPC also requested that the HCPD be the accepting agency for an Environmental Impact Statement (EIS) that TPC would voluntarily prepare and submit for the PGV Project. Although the HCPD determined that there were no clear requirements for preparation of an EIS, the HCPD agreed to act as accepting agency for the EIS and deferred acceptance of the PGV Project GRP application until after acceptance of the EIS. The Final EIS for the PGV Project was accepted on December 28, 1987, although the Hawaii County Planning Director again noted that the PGV Project did not require the filing of an EIS. However, further processing of the GRP application has not occurred because the entire interest in the PGV partnership was purchased during the first half of 1988 by AMOR VI Corporation and AMOR VIII Corporation (AMOR Corporations), two wholly-owned subsidiaries of Ormat Energy Systems, Inc. of Sparks, Nevada.

Since the purchase, PGV has reviewed the previous design of the PGV Project to determine if it remains entirely appropriate. As a result of this design review, PGV has decided to alter several aspects of the previously proposed PGV Project design to optimize production operations and further reduce the potential for environmental impacts. Principal among these proposed changes is the use in the power plant of back-pressure steam turbines, in combination with air-cooled binary cycle turbines, in place of the steam turbines and cooling towers proposed by TPC. This currently proposed power plant configuration applies a closed cycle for the geothermal fluid, thus essentially eliminating hydrogen sulfide emissions during normal operations and eliminating the need for cooling towers. Most other environmental impacts from this revised PGV Project will be very similar to those of the previously proposed PGV Project because the revised PGV Project will use the same geothermal resource, the same geothermal wellpads, and the same power plant location as the previously proposed PGV Project.

This amendment to the GRP application has been prepared to replace, in its entirety, the GRP application submitted to the

Hawaii County Planning Department in December, 1986. For clarity sake, Chapter 2 of this application is a summary description of the revised PGV Project, drawing comparisons with the previously proposed PGV Project, as appropriate. A more detailed description of the revised PGV Project follows in Chapter 3, organized to follow the requirements of Rule 12, Geothermal Resource Permits, of the County of Hawaii Planning Commission Rules of Practice and Procedure. As required by Rule 12, Chapter 3 of this amended application also summarizes the PGV Project potential environmental impacts and mitigation measures. See Appendix A for a list of abbreviations used in this GRP Application.

2. PROJECT SUMMARY

The proposed PGV Project is located approximately 21 miles southeast of the city of Hilo in the Puna District of the Island of Hawaii (see Figure 2-1). The project will occupy about 25 acres of surface area within a dedicated 500-acre project area in the Kapoho section of the Kilauea Lower East Rift Geothermal Resource Subzone. The Kilauea Lower East Rift subzone was established in 1984 (Act 151) under Chapter 205, Hawaii Revised Statutes, which mandates the designation of geothermal resource subzones for geothermal exploration and development.

The proposed PGV Project is designed to generate 25 MW (net) of electrical energy from geothermal fluids produced from the Puna geothermal field. The project, which is planned for an operating life of 35 years, will consist of:

- ten (10) integrated back-pressure steam turbine and air-cooled binary cycle turbine power generating modules;

- up to 30 geothermal wells drilled from six (6) wellpads;

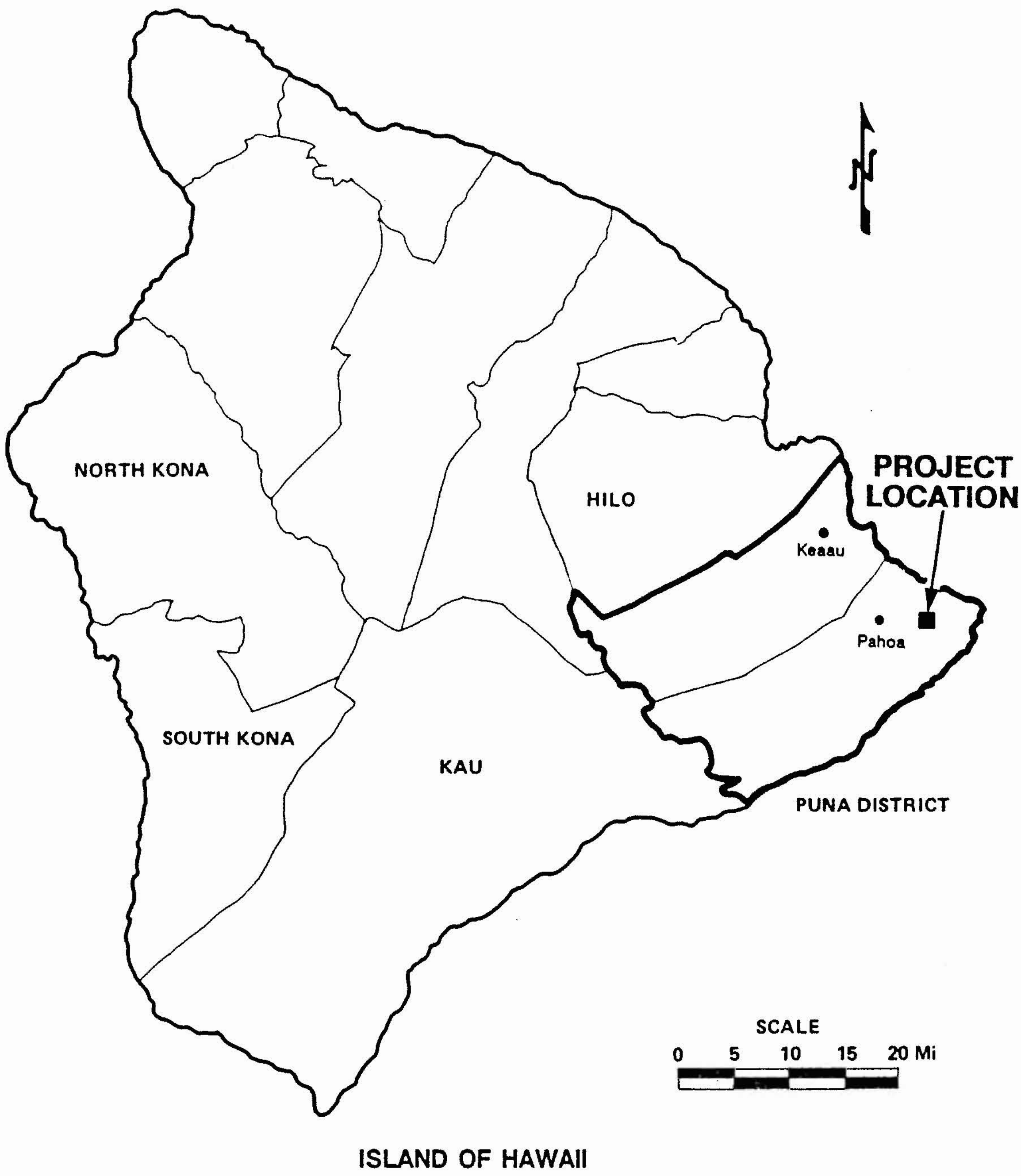
- brine and steam pipelines;

- pollution control equipment;

- a brine surge tank and holding pond;

- a switchyard;

- an office, warehouse, workshop, and control buildings;



SOURCE: State of Hawaii, Department of Planning and Economic Development, STATISTICAL BOUNDARIES A-15. 1980:14

Figure 2-1. Location of the Puna District

- access roads; and

- auxiliary facilities such as air compressors, fire protection equipment, etc.

Figure 2-2 shows the locations of the major project facilities. The project will deliver 25 MW (net) to the switchyard, where the power will be purchased by HELCO to provide electricity to the Island of Hawaii.

The geothermal resources in the Puna geothermal area, located at depths generally greater than 4,000 feet, beneath impermeable caprock, are in excess of 600°F. The geothermal fluids produced from the Puna geothermal field are expected to contain a mixture of approximately 80 percent steam and 20 percent liquid at a pressure of about 200 psig and a temperature of about 390°F.

2.1.Wellfield Facilities

The proposed PGV Project will use the same geothermal wellpads and wellfield as the previously proposed PGV Project, as shown in Figure 2-2. Initially, the project is anticipated to require eight (8) production wells and two (2) injection wells, although the number of initial production wells may range from seven (7) to nine (9) and a third injection well may be necessary. Allowing for up to two (2) unusable wells (dry holes), nine (9) to fourteen (14) wells will need to be drilled for initial full-capacity operation. All wells will be drilled form up to six (6) wellpads. Additional makeup wells will need to be drilled over the 35-year economic life of the PGV Project, although all wells will be drilled from one of the six wellpads, and no more than a maximum of five (5) wells per wellpad will be

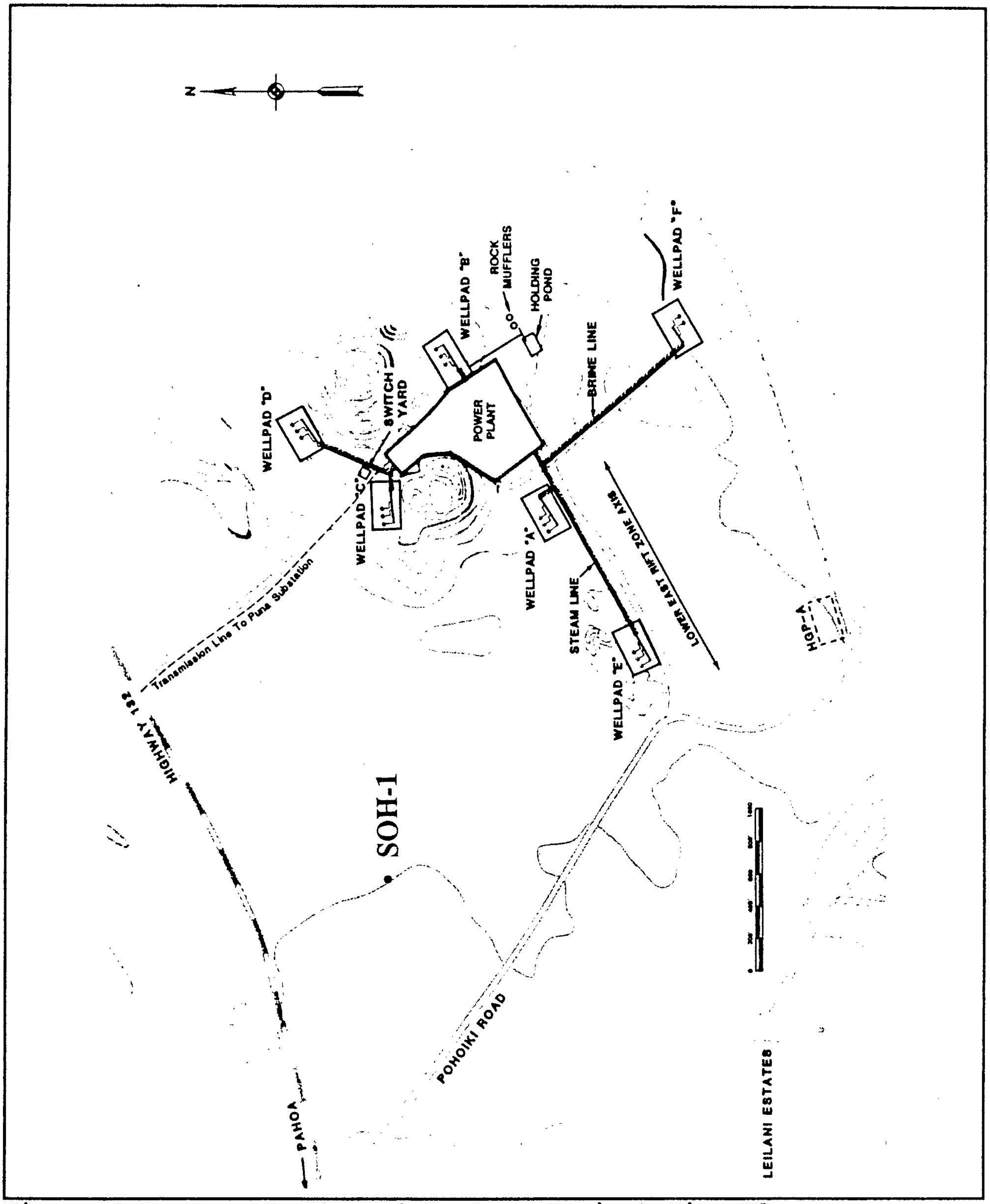


Figure 2-2. Puna Geothermal Venture Project Site Plan

drilled, for a maximum total of not more than 30 wells. Both production and injection wells will be drilled and cased down into the geothermal reservoir.

Each production well is expected to produce between 55,000 to 90,000 pounds per hour (lb/hr) of usable steam at a pressure of approximately 200 pounds per square inch gauge (psig) and a temperature of 387°F at the wellhead, as well as 14,000 to 22,000 lb/hr of geothermal brine and approximately 50 to 120 lb/hr hydrogen sulfide (H_2S).

Most drilling will be performed using drilling muds which produce negligible H_2S and particulate emissions, While drilling in the production zone, aerated water or aerated mud, may be used as the circulating medium. Occasional inadvertent releases of steam during drilling with aerated water or aerated mud will be limited to five (5) to ten (10) minutes, which will produce emissions of 7.0 lb H_2S or less during any one event. A cyclone separator will control particulate emissions during these steam releases.

Best Available Control Technology (BACT) will be applied during well testing. After venting to cleanout the well bore, each well will be connected to a separator which will partition the steam and gases from the brine. The steamline will be equipped with chemical abatement equipment to abate H_2S emissions by 95 percent. The steam will then be released through a rock muffler to muffle the noise.

All of the wells at each wellpad will be connected to a flash separator that will partition the geothermal brine from the geothermal steam and noncondensable gases. At least two wellfield gathering systems will be used to move the geothermal brine and geothermal steam to the power plant. A third pipeline may be needed to collect geothermal steam condensate produced by heat losses in the steam gathering lines. These pipelines will gather the appropriate fluid(s) and gases from each wellpad and will be routed to the power plant site together and, where practical, adjacent to the wellpad access roads. The steam will be delivered to the power plant system; the brine will be delivered to the brine surge tank for injection.

Under normal power plant operations, essentially all of the geothermal fluids produced by the production wells and all of the noncondensable gases will be returned to the geothermal reservoir through the injection wells. In the present design, after the steam has passed through the power plant system and been condensed, the steam condensate will be mixed with the geothermal brine from the brine surge tank. The noncondensable gases will then be injected into the condensate/brine mixture, and this recombined geothermal fluid will then be injected back into the geothermal reservoir.

2.2.Power Production

The PGV Project will generate up to 28.5 MW of electrical power so that 25 MW can be delivered to the HELCO electric grid system, with the balance of the power being consumed by the plant equipment. The actual amount of power generated will vary in response to steam quantities, atmospheric temperatures and other operating conditions.

Several changes have been proposed to the previous PGV Project power plant design to increase project reliability and flexibility, decrease construction time and reduce the potential for emission of air contaminants.

The design of the power plant has been modified by:

- utilizing ten (10) nominal 3 MW modular turbine-generating units instead of two (2) 15 MW turbine-generator units. Each module will contain the following turbine-generating equipment:
  - a nominal 1.8 MW back-pressure steam turbine,
  - a nominal 1.2 MW binary cycle turbine that generates additional electricity from the low-pressure steam leaving the back-pressure turbines, and
  - a common 3 MW generator;
- utilizing air-cooled condensers for the working fluid in the binary cycle instead of the water-cooled condensers, thus eliminating the cooling towers and the release of gases; and
- injecting <u>all</u> of the produced geothermal fluids (geothermal brine, steam condensate and noncondensable gases) back into the geothermal reservoir, thus eliminating all but negligible fugitive emissions of hydrogen sulfide during normal operations.

Figure 2-3 shows a simple schematic diagram of the PGV Project steam turbine/binary cycle power plant system.

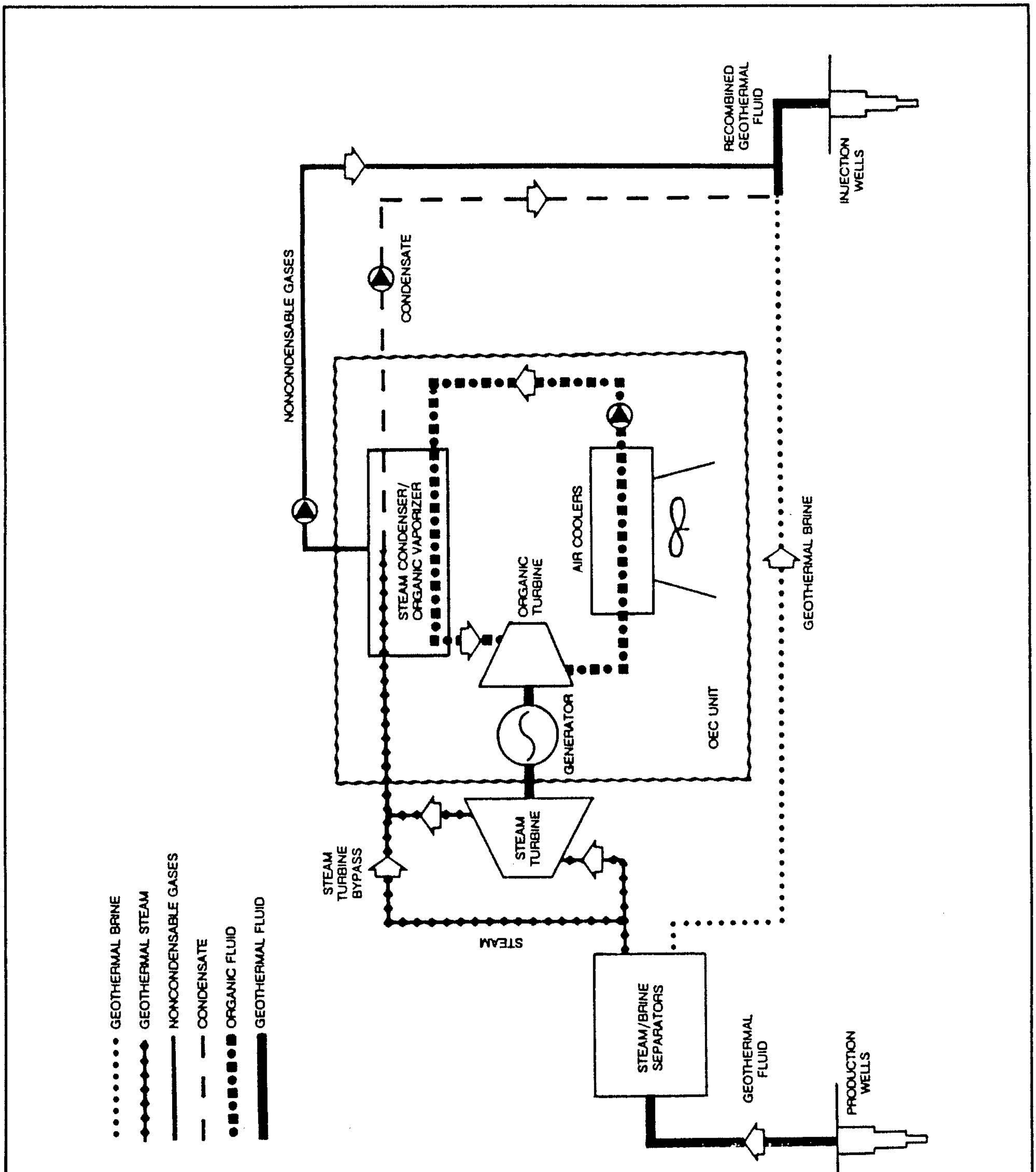


Figure 2-3. Simplified Process Flow Diagram

The proposed 1.8 MW modular back-pressure steam turbines operate much the same as the condensing steam turbines proposed in the previous PGV Project design, but the steam leaving the back-pressure turbines remains slightly above atmospheric pressure. Thus, the steam retains a significant amount of heat energy which is converted into electricity by the binary power generating units, known as Ormat Energy Converter (OEC) units. These OEC units, manufactured by Ormat Turbines, Ltd., apply principles and technologies well-tested in various industries and successfully applied in other geothermal fields throughout the world.

The OECs operate on the same basic principles as steam turbines, but use an entirely closed organic working fluid system instead of steam. OECs use the heat energy of the geothermal fluid to vaporize the organic working fluid (isopentane), which expands through a small turbine to generate electricity. The isopentane vapor is then condensed back into a liquid state in a condenser.

The PGV Project is also proposing that the binary working fluid condenser be cooled with air, rather than with water. Air cooling is also a well-tested technology that has been utilized in previous geothermal power plants. In this system, the binary working fluid vapor leaving the organic fluid turbines goes to the air coolers, where large fans force air across tubes containing the vapor. This air cools the binary working fluid vapor and condenses it into a liquid which is collected and routed back to the vaporizer and the turbines. Because air coolers have replaced the cooling towers, the PGV Project does not need to utilize the geothermal steam condensate as cooling tower makeup water. Thus, all the geothermal fluids (brine, steam condensate, and noncondensable gases) produced by the production wells can be injected back into the geothermal reservoir via injection wells.

The back-pressure steam turbine/binary cycle power plant is a closed system that, during normal operations, does not release any H_2S or other gases to the atmosphere. The geothermal fluids at the Puna field contains up to 1300 ppm H_2S and 600 ppm carbon dioxide (CO_2). A small fraction of the noncondensable gases will remain in the geothermal brine during the initial separation process. However, most of the noncondensable gases will be partitioned with the steam during the initial separation process, pass through the steam turbine, and be routed along with the low pressure steam to the heat exchangers in the OEC units. There the working fluid will condense the steam. The steam condensate will then be mixed with the brine for injection. The remaining gases, still under low pressure, will exit the OEC units and be compressed, and injected into the mixture of condensate and brine, and the recombined stream injected into the geothermal reservoir.

The process of dissolving H_2S and/or CO_2 into water is common practice in the field of chemical engineering. Injection of the combined fluid stream into the geothermal reservoir has been successfully demonstrated at the Coso geothermal field in California since July, 1987. Based on these results, the noncondensable gases produced from the Puna geothermal reservoir will be dissolved and entrained in the produced geothermal fluids by in-line mixing, and all of the produced fluids and gases will be injected into the geothermal reservoir. To ensure the reliability of the injection system, a spare pump, a spare compressor, and a spare injection well will be provided. A holding pond is provided to collect liquids for the unlikely event of an upset in the liquid injection system.

A major advantage of the proposed design is the ability of the OEC units to operate on high temperature steam when the steam portion of the module is not operating. Thus, when one or more steam turbines fail, the power plant can continue to operate, although at reduced rates; the actual rate of reduction will depend on the number of steam turbines that are shutdown. As long as the entire power plant uses at least 50 percent of the steam flow, there will be no emergency steam release.

To enable this mode of operation, a steam turbine bypass system will be installed on each steam turbine unit so that its OEC unit can operate even when the steam turbine portion is not in operation (such as during plant start-up). In this situation, the geothermal steam bypasses the steam turbine and enters directly into the OEC vaporizer, where it condenses as during normal operating conditions.

When the entire power plant is shut down, an emergency steam release facility will be used to release steam, treated with sodium hydroxide (NaOH) to remove 96 percent of the H_2S, through a rock muffler (which will reduce noise levels) while the wellfield production rate is being reduced to 50 percent of full flow. After this reduction, the power plant will emit less than 2 percent of full flow uncontrolled H_2S (98 percent control) until normal operation is resumed.

3. DETAILED DESCRIPTION OF PROPOSED ACTION

Planning Commission Rule 12-3 provides a detailed description of the information which must be contained in a Geothermal Resource Permit application. The discussion that follows is arranged to coincide with the order of Items 12-3(b)(2) parts (A) through (P). The relevant Rule 12 description is included at the beginning of each subsection.

3.1. Location and Description of Property

This subsection provides "a description of the property for which a permit is being requested to include the property's real property tax map key designation and a description of the property's location within the County" as required by Rule 12-3(b)(2) part (A).

The 500-acre PGV Project area, for which the PGV Project is requesting a Geothermal Resource Permit, is located in the Puna District of the County of Hawaii, approximately 21 miles southeast of the city of Hilo, in the Kapoho Section of the Kilauea Lower East Rift Geothermal Resource Subzone (see Figure 2-1). The entire PGV Project area was designated as a geothermal resource subzone in 1984 by Act 151 of the Hawaii legislature. The PGV Project area was one of three areas established as subzones since the landowners of these areas had already obtained State geothermal mining leases and developers of the lands had been issued County special use permits for geothermal development activities.

Specifically, the approximately 500-acre PGV Project area consists of the following properties, as identified by their Tax Map Key designations:

- TMK 1-4-01:2 (portion) containing approximately 300 acres
- TMK 1-4-01:3 (all) containing 3.741 acres
- TMK 1-4-01:19 (portion) containing approximately 200 acres
- TMK 1-4-01:58 (all) containing 0.0758 acres

This is the total area, surface and subsurface, over which PGV intends to conduct the PGV Project, although the actual permanent surface disturbance from the project will be limited to approximately 24.5 acres within this approximately 500-acre parcel (see Section 3.6). The 500-acre PGV Project area (see Figure 3-1) is contained entirely within an 816-acre parcel that PGV subleases from the Kapoho Land Partnership (KLP). The PGV sublease includes the right to develop the geothermal resources and utilize as much of the surface lands within the subleased lands as reasonably necessary to develop the geothermal resources, subject to KLP's right to develop non-competing uses. KLP holds the surface rights to the parcel and has obtained a State of Hawaii Geothermal Mining Lease (R-2), which includes the rights to the geothermal resource. KLP's State lease has been assigned to PGV.

The wellpad and power plant locations are situated on scrub vegetation and fallow fields. The dominant vegetation is non-native weedy species and abandoned papaya orchards. Much of the area within one mile of the power plant is covered by either the 1955 lava flow, fallow fields or Metrosideros forests. Scattered residences are found outside the project boundary.

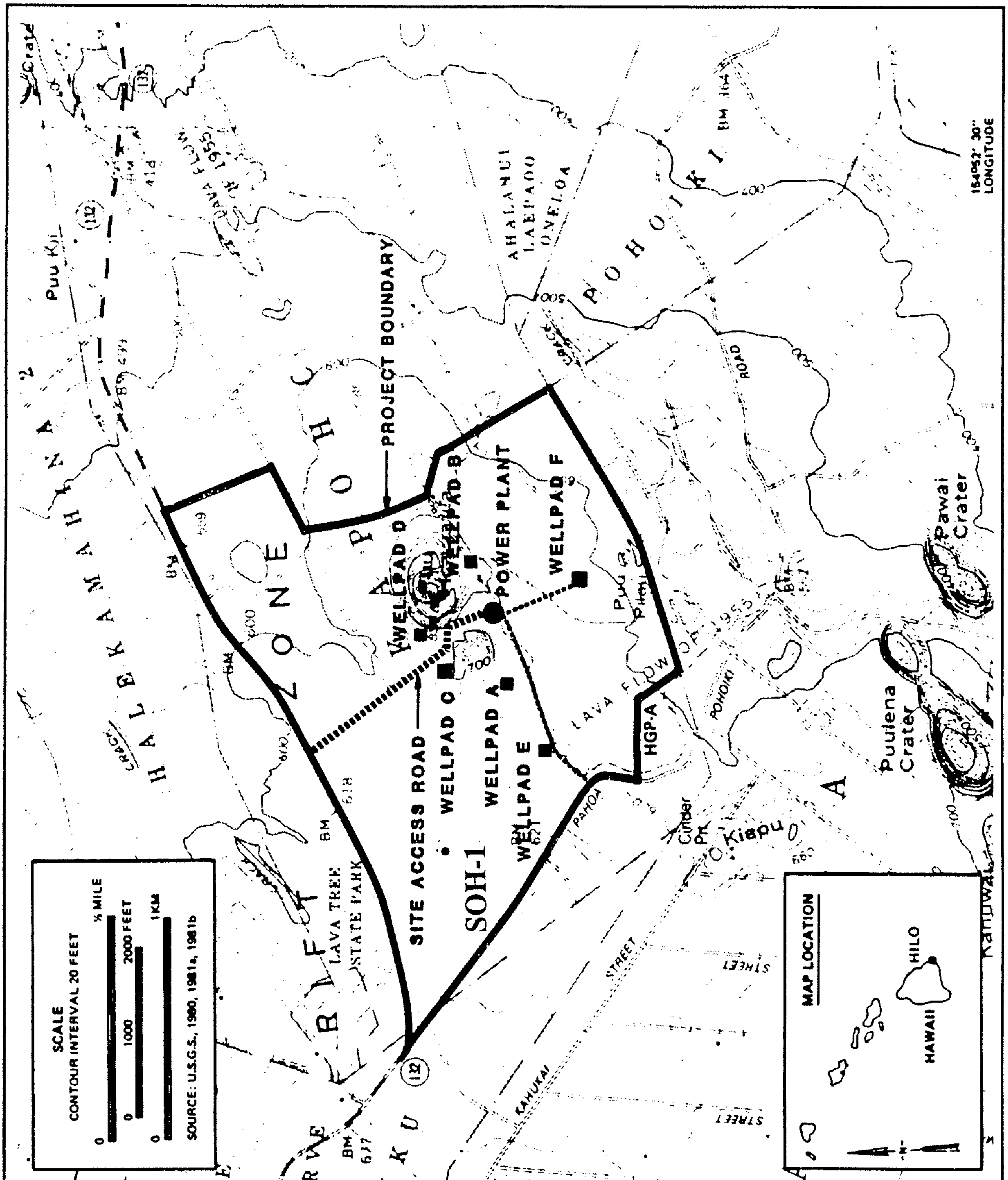


Figure 3-1. Puna Geothermal Venture Project Area and Vicinity Map

3.2. Project Scope and Description

This subsection provides "a written statement describing the scope of the planned activities and presenting the applicant's reasons for requesting the permit" as required by Rule 12-3(b)(2) part (B).

PGV is applying for a Geothermal Resource Permit in order to develop the Puna geothermal resource for the generation of electrical power to furnish 25 MW of electrical capacity to HELCO's energy grid system.

PGV seeks approval from the County of Hawaii Planning Commission for the construction of a geothermal power plant, associated wellfield and gathering system, and all roads, buildings, and facilities necessary for safe, effective development. A detailed description of the project is presented below.

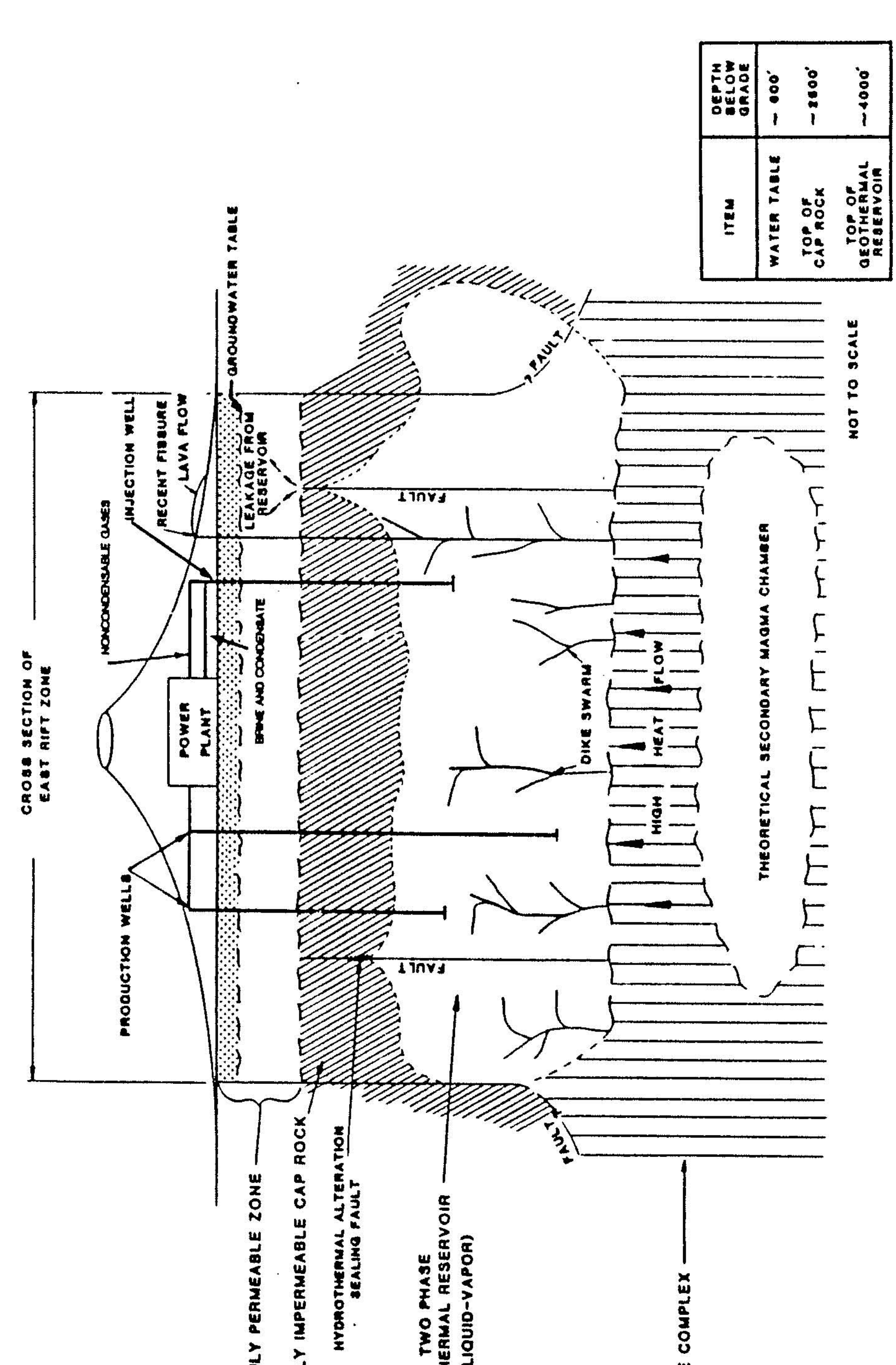
3.2.1. Geothermal Wellfield Facilities

3.2.1.1. Wellfield Development Plan

The PGV Project is located in a geologic region known as the Lower East Rift Zone (LERZ), found on the eastern flank of Kilauea Volcano. At depths below 8,000 feet beneath the surface features of the LERZ, a 5- to 15-mile wide dike complex is thought to exist, where temperatures approach 1,900°F, the melting point of basalt. A secondary magma chamber may be located within the LERZ beneath the geothermal reservoir. The series of dikes are thought to convey heat to the high-temperature geothermal reservoir, a system of vertical to near-vertical fractures which contains, below 4,000 feet, a two-phase geothermal resource with temperatures as high as 600°F. Overlying the high-temperature geothermal reservoir is a relatively impermeable layer of capping rock, generally at depths of between 4,000 and 2,500 feet below the surface, although both the upper and lower boundaries are variable and dependent upon the local permeability (fractures). A conceptual model of the Puna geothermal reservoir is presented in Figure 3-2.

To date, six deep test wells have been drilled in the general PGV Project area (see Figure 3-3). Four of the wells appear to have been drilled into the high-temperature Puna geothermal reservoir, as they encountered temperatures in excess of 600°F at depths below 4,000 feet: Kapoho State 1 (KS-1) and Kapoho State 1-A (KS-1A), drilled from PGV Wellpad A; Kapoho State 2 (KS-2), drilled from PGV Wellpad B, and the HGP-A well. Currently, KS-1 and KS-2 are suspended with cement plugs in their bores, and KS-1A is closed in (shut in). The fourth well, HGP-A, is currently producing steam for the 3 MW HGP-A demonstration plant, which is located immediately outside the PGV Project boundary, south of proposed PGV Wellpad E. The other two wells, Lanipuna 1 and Lanapuna 6, encountered lower temperatures and appear to be located on, and define, the southeast margin of the high temperature geothermal system in the immediate area.

The proposed PGV Project geothermal wellfield development plan has been designed to maximize the possibility of drilling geothermal production wells that intersect, below approximately 4,000 feet, these near-vertical fractures, which are generally aligned along the axis of the LERZ and which carry the geothermal fluids. To accomplish this, geothermal wells will be directionally drilled in general southeast and northwest



ITEM	DEPTH BELOW GRADE
WATER TABLE	~ 600'
TOP OF CAP ROCK	~2600'
TOP OF GEOTHERMAL RESERVOIR	~4000'

Figure 3-11 CONCEPTUAL MODEL OF THE PUNA GEOTHERMAL RESERVOIR

Figure 3-2. Conceptual Model of the Puna Geothermal Reservoir

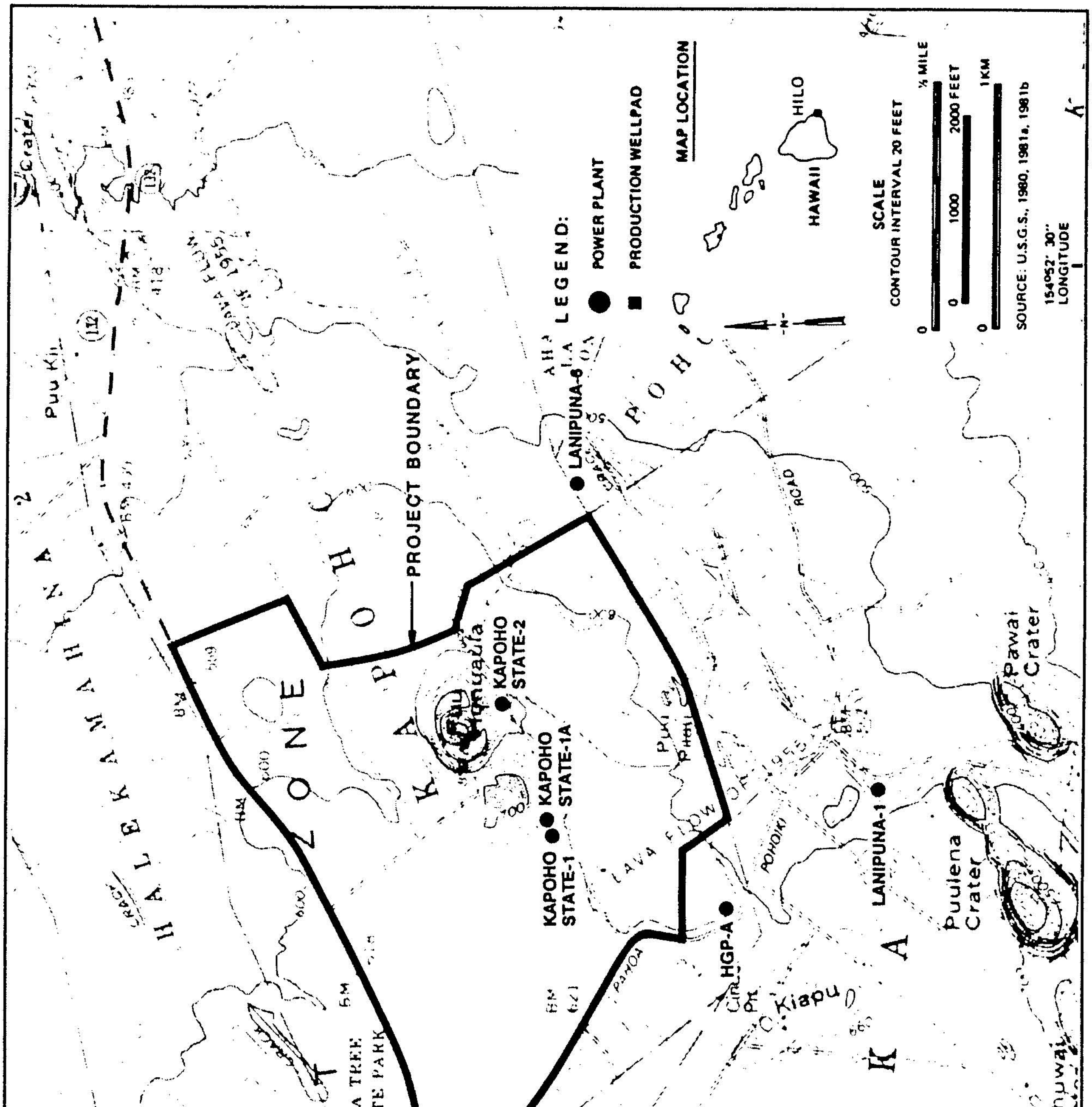


Figure 3-3. Existing Geothermal Wells in the Puna Geothermal Venture Project Area

directions from the six multi-well wellpads shown in Figure 3-4. As stated above, geothermal exploration wells have already been drilled from Wellpads A and B. The proposed sites for the four additional wellpads (Wellpads C, D, E and F) were selected on basis of proximity to the power plant, current knowledge of reservoir extent, optimal drilling targets, directional drilling experiences, and injection needs. In order to optimize wellfield production with low surface area requirements, these proposed wellpad locations may require relocation within the proposed 500-acre PGV Project area after additional drilling, production, injection, or other information becomes available. The approximate elevations of the wellpads in feet above mean sea level (AMSL) are given in Table 3-1.

Table 3-1. Geothermal Wellpad Elevations

Description	Elevation
Wellpad A	640 feet
Wellpad B	720 feet
Wellpad C	680 feet
Wellpad D	700 feet
Wellpad E	620 feet
Wellpad F	620 feet

Table 3-2 presents the current initial geothermal well development plan for the PGV Project. Based upon drilling and flow testing experience to date, and projections of future performance, PGV has designed its wellfield for wells that produce approximately 62,500 lb/hr steam, with any individual

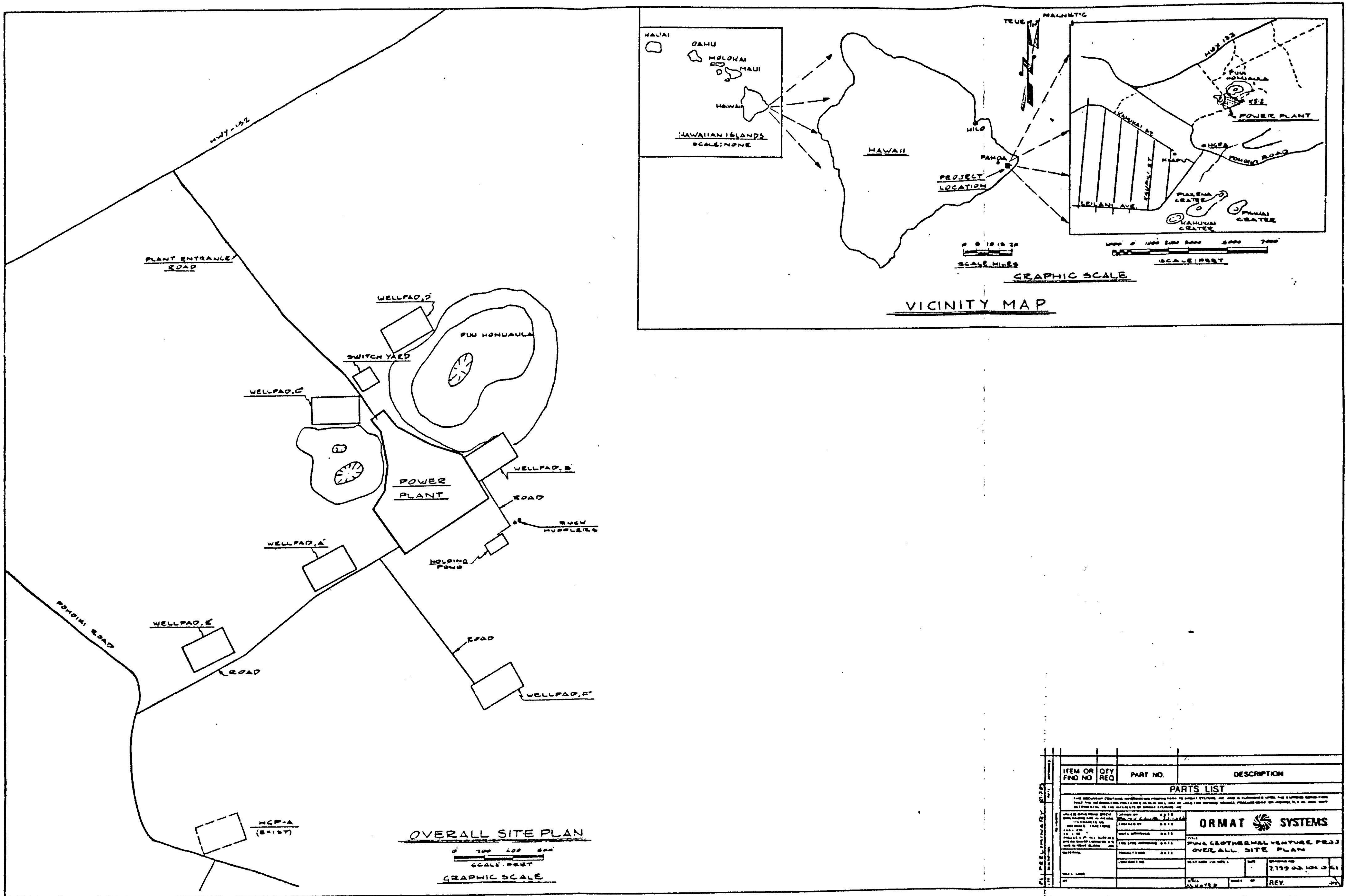


Figure 3-4

Figure 3-4. Puna Geothermal Venture Project Overall Site Plan (Dwg. No. 7.799.00.101.0)

Table 3-2. Initial Well Development Plan

Type of Well	Anticipated	Range
Production Wells	8	7 - 9
Injection Wells	2	2 - 3
Allowance for Unusable Wells	0	0 - 2
Total Initial Wells	10	9 - 14

well producing between 55,000 and 90,000 lb/hr steam. Thus, PGV anticipates that eight (8) production wells will be needed to supply the anticipated steam requirements of 500,000 lb/hr for the power plant at full load, although depending on the actual production rate of the wells, seven (7) to nine (9) wells may eventually supply the steam requirements of the project. To dispose of the produced geothermal brine and geothermal steam condensate, two (2) wells have been planned as geothermal injection wells; one for ongoing use and one as a spare, although a third well may be necessary. Some wells with poor production characteristics may ultimately be used as injection wells, but it is currently anticipated that wells will be drilled specifically for the injection of geothermal fluids. Additional wells are also included in the initial geothermal well development plan to allow for the possibility of drilling unsuccessful wells which terminate in impermeable rock.

Once sufficient wells are drilled to supply the initial production and injection requirements of the power plant, additional wells will be drilled as needed to supplement replace wells which have lost production or injection capacity, which is a normal occurrence in all geothermal fields. Over the 35-year life of

Table 3-3. Anticipated Initial Geothermal Well Development Sequence

	Wellpad and Well Number	
Drilling Sequence	Production Wells	Injection Wells
Existing	A-2 (KS-1A)	
First	E-1	F-1
Second	E-2	F-2
Third	A-3	F-3
Fourth	A-4	
Fifth	D-1	
Sixth	D-2	
Seventh	E-3	
Eighth	E-4	
Ninth	B-2	

the PGV Project, it may be necessary to drill as many as 30 geothermal wells, the maximum number of wells which can be drilled from the six proposed wellpads (see Section 3.2.1.2).

The currently anticipated well development sequence for the initially required production and injection wells is shown in Table 3-3. The first well listed in Table 3-3, Well A-2 (KS-1A), already exists. The other wells in the project area, A-1 (KS-1) and B-1 (KS-2), are cemented in and will not be used. The drilling sequence proposed for the next seven wells reflects the overall strategy to drill wells with the highest resource confidence level first, followed progressively by those in more uncertain areas, with a significant consideration given to minimizing the number of times the drilling rig must move between wellpads. This proposed drilling sequence will be reviewed and changed, if necessary, after the completion of each well as additional information is gathered about the geothermal reservoir. At present, of the existing three wells, only KS-1A will be used as a production well for the PGV Project. Further, no wells are currently planned for Wellpad C in the initial development, and this wellpad will be kept in reserve for the drilling of makeup wells when necessary.

The specific bottom hole drilling target for each well cannot be determined precisely with the reservoir information now available, but, because wells will be directionally drilled from the wellpads, the bottom hole locations may be up to 1,500 feet horizontally distant from the wellhead. However, all bottom hole locations will remain within the 500-acre PGV Project area boundary. Specific bottom hole targets will be identified for each geothermal well in the drilling permit application which is required by the Hawaii State Department of Land and Natural Resources (DLNR) to be submitted to, and approved by, the DLNR prior to commencing drilling.

3.2.1.2.Wellpads and Access Roads

Each wellpad will measure approximately 300 by 400 feet, and will be designed to accommodate the drilling of up to five wells (see Figure 3-5). The wellheads will be placed in cellars approximately 10 by 10 by 8 feet deep (see Figure 3-6), and will be set about 50 to 100 feet apart within the wellpad. Each wellpad will be a leveled area large enough to accommodate the drilling rig and all the drilling support equipment, structures and crews. Each site will be engineered to support the drilling equipment and to keep drilling effluent contained onsite and separate from any natural drainage. Each wellpad will have drilling mud pits; sumps with gently sloped walls used to

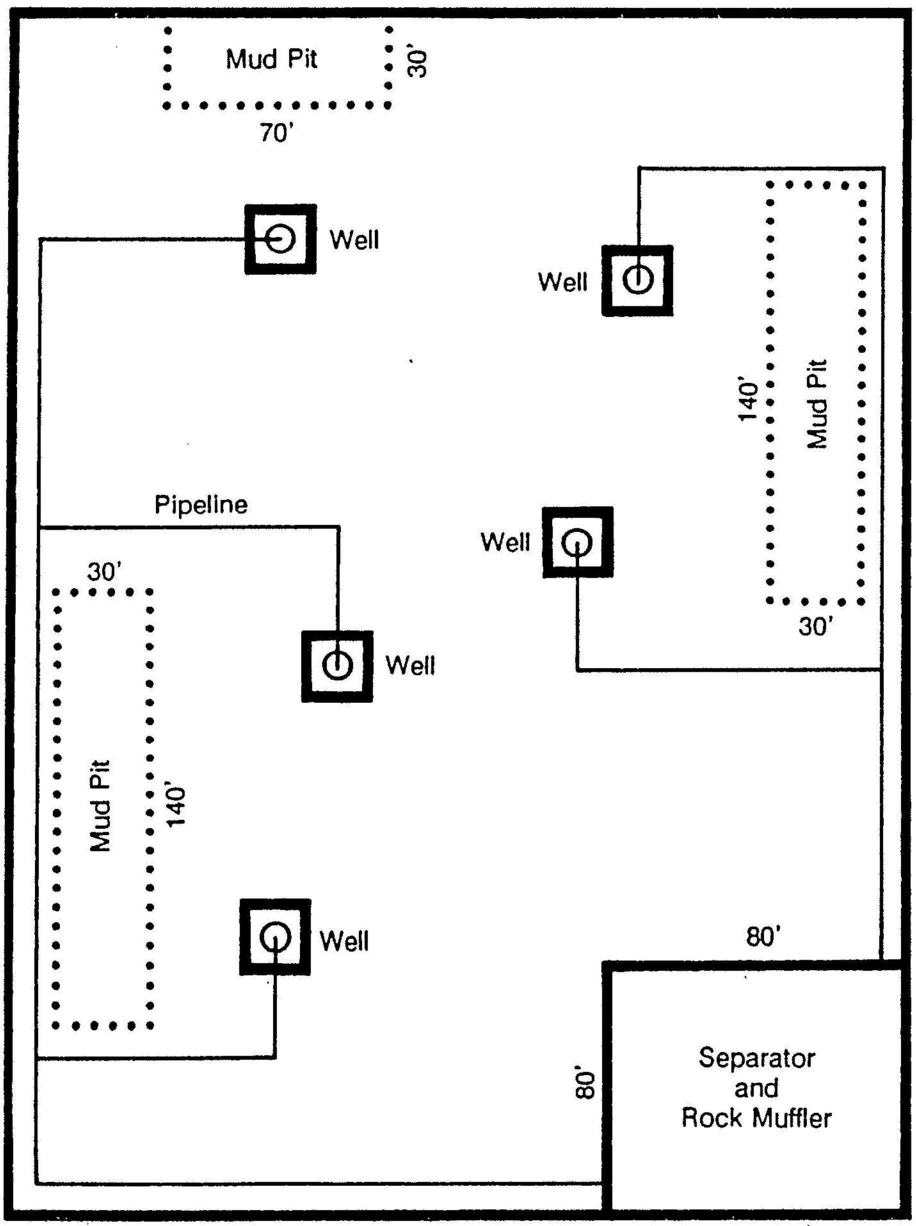


Figure 3-5. Proposed Puna Geothermal Venture Project Wellpad Layout

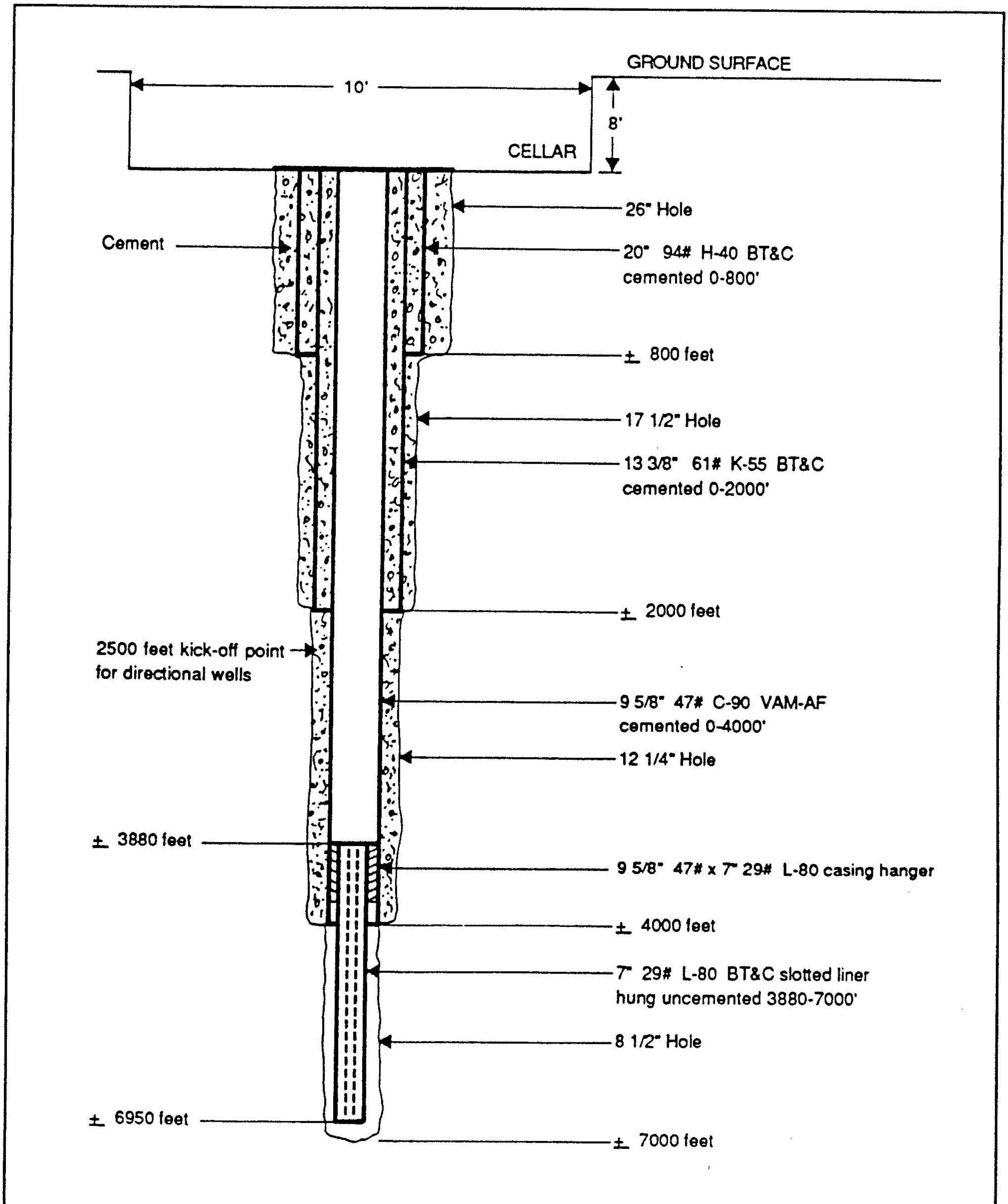


Figure 3-6. Typical Production Well Design

temporarily store drilling wastes, which typically consist of rock cuttings, waste drilling mud, cement particles, lost-circulation material and other drilling mud additives, and other waste drilling liquids.

Once drilling and initial testing of the wells on a wellpad is complete, the drilling rig will be removed and only the rock muffler, a brine/steam separator, and associated piping will remain on the pad. However, the wellpad area must be maintained to allow the return of the drilling rig should any of the wells need to be worked over or new wells drilled from the wellpad.

The existing site access road to the project area is from Pahoa-Pohoiki Road. A new access road is planned from Highway 132, and the existing road will not be used in most instances. To mitigate potential traffic congestion and accidents relating to traffic on Highway 132, a right-hand turn lane will be constructed for vehicles turning into the site off Highway 132. The locations of both of the roads are depicted in the site plan (Figure 2-2). The main access road will allow two-way traffic and will meet local standards for its expected use. The single-lane interior service roads will be about 15 feet wide, surfaced with cinders, and built to accommodate the large trucks used to bring the drilling and testing equipment to the wellpads.

3.2.1.3. Well Drilling

Figure 3-7 shows how the equipment required to drill the geothermal resource wells might appear during drilling operations. This equipment consists of the mast or derrick, pipe racks and drill pipe, mud mixing tanks, mud pumps and air

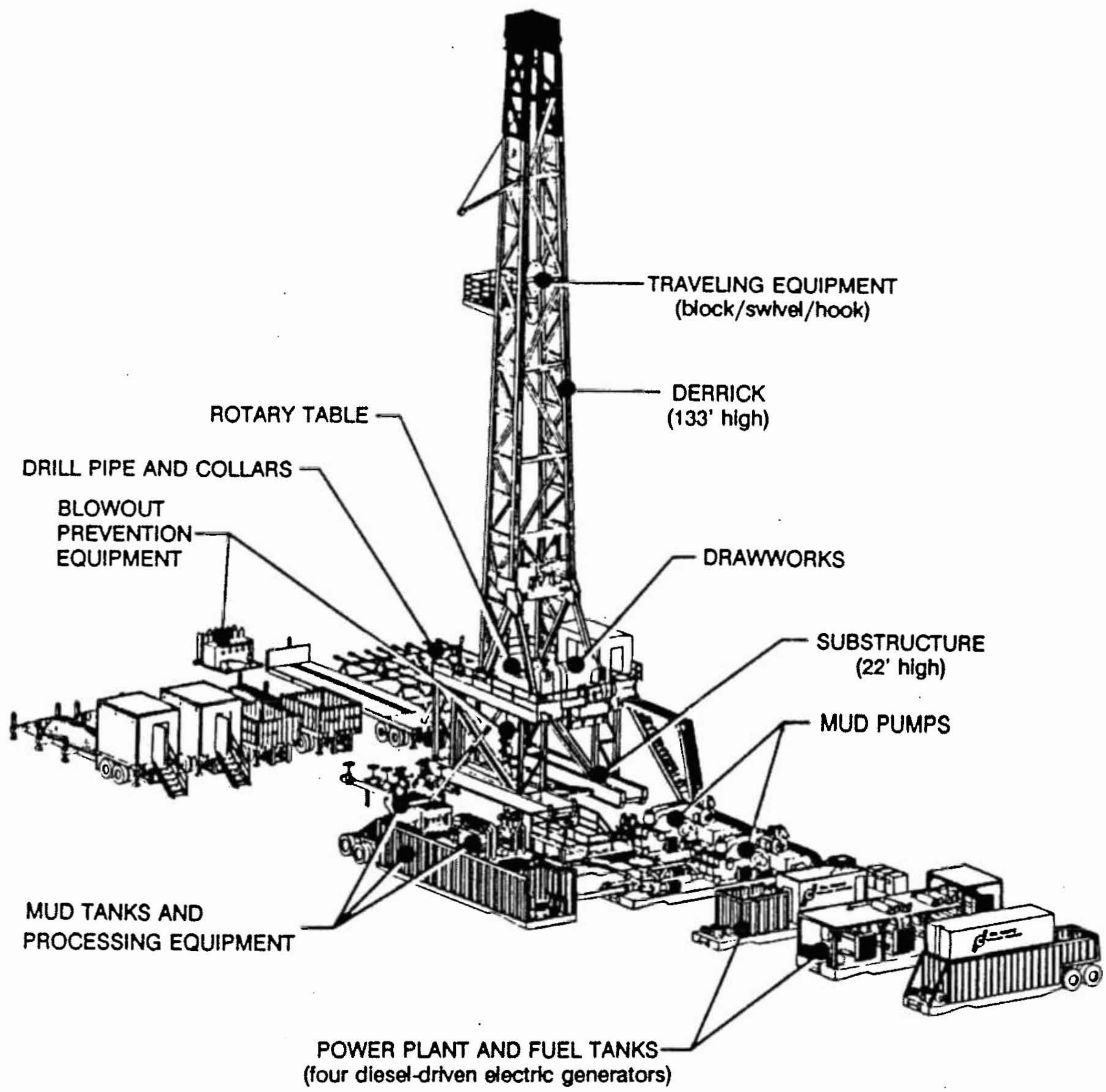


Figure 3-7. View of a Typical Geothermal Well Drilling Operation

compressors, diesel engines, blowout prevention equipment, a muffler or separator for well testing, fuel and drilling water storage water tanks, hydrogen sulfide abatement equipment, and a trailer office, change house, and restrooms for the crews.

The drilling rig will consist of a rig floor with draw works and a rotating table on a steel base structure to raise the rig floor about 20 feet off the ground to allow space for the wellhead and well-control equipment used in drilling. The rig floor is topped by a mast, or derrick, about 130 feet high. The entire rig will be powered by electricity generated by onsite diesel engines. A tank of approximately 11,000 gallons will store the No. 2 diesel fuel oil.

Drilling operations will be conducted on a 24-hour a day, 7-day per week basis until each well is completed. During drilling the wellhead is equipped with a set of control valves which collectively compose the blowout prevention equipment (BOPE). The BOPE is capable of closing (shutting) in a well during drilling operations to contain underground fluids inside the well and prevent any uncontrolled release of geothermal fluids at the wellhead. The BOPE is frequently tested to ensure its proper operation in an emergency.

During drilling in the upper part of the hole, the circulation fluid will be drilling mud, a mixture predominantly of bentonite clay and water, with other, mostly inert, nontoxic additives included in small amounts. See Figure 3-8 for the basic elements of a rotary drilling rig of the type that will be used by the PGV Project. During the final phases of drilling in the production zone, aerated water or aerated mud may be used instead of drilling muds. Drilling muds are typically used in those

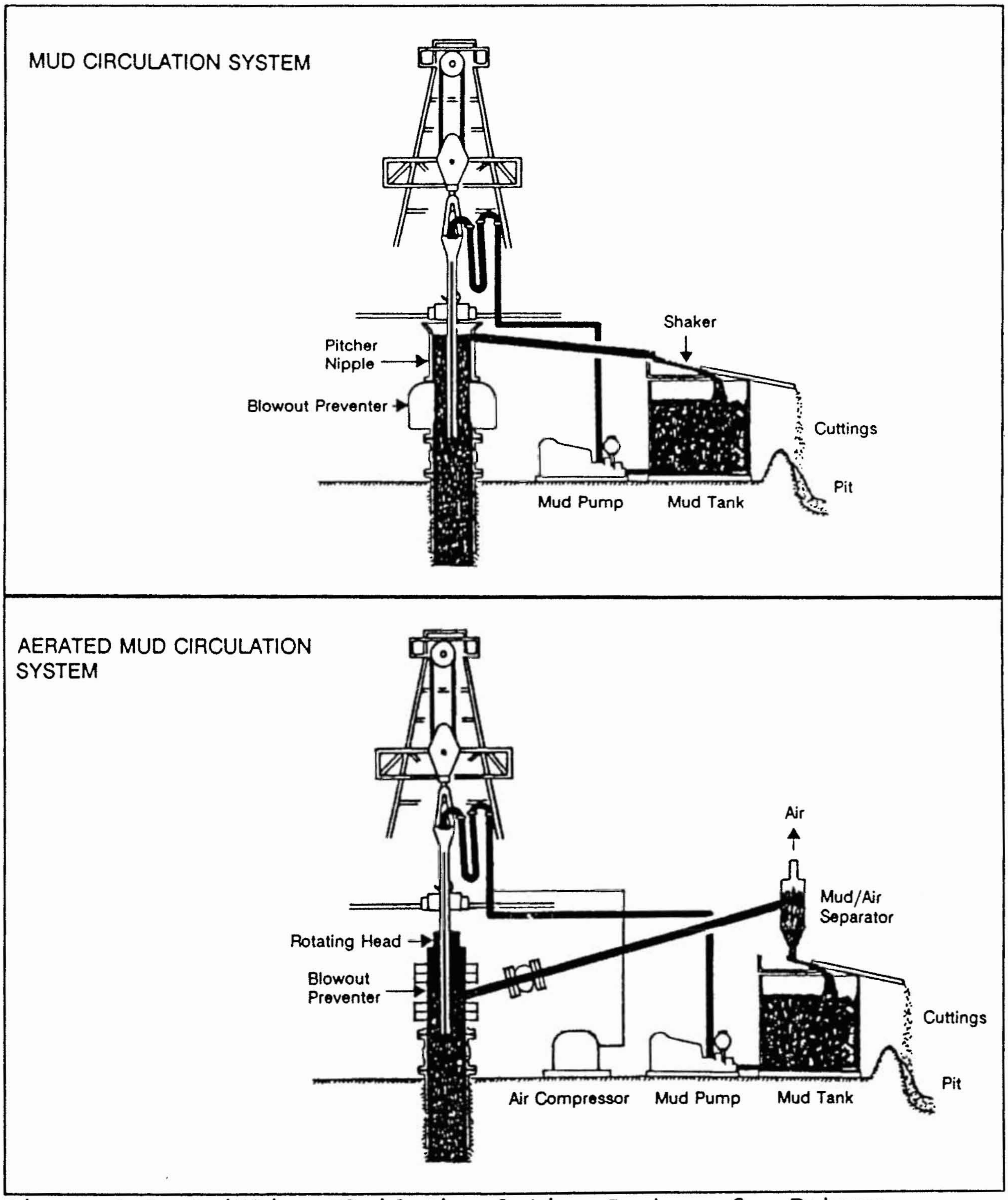


Figure 3-8. Drilling Fluid Circulation System of a Rotary Drilling Rig

portions of the well where water is expected, whereas the reservoir intervals of wells in geothermal fields containing high percentages of steam are preferably drilled with air or aerated water. Drilling typically requires about 30,000 gallons of water per day for the preparation of new drilling fluid, washing of the rig, and other uses.

While drilling with aerated water or aerated mud, which should last no more than about 10 days, pressure of the liquid column of the drilling fluid is greater than the pressure in the reservoir and normally there will be no emission of steam and noncondensables. Occasionally, (about two to six times during the aerated water or mud drilling period) when the pressure of the reservoir overcomes the pressure of the drilling fluid, some steam with noncondensable gases may enter the wellbore and be vented to the atmosphere for a brief period of five (5) to ten (10) minutes. At ten minutes of full steam flow through the annulus (5,000 lb), total unabated hourly emissions will be less than 7 lb of H_2S. If a release occurs, the drilling fluid weight will be immediately increased, stopping the steam flow. If the pressure cannot be restored quickly enough, the BOP equipment will be used to control the flow.

All wells will be drilled into the geothermal reservoir, which starts at a depth of approximately 4,000 feet below the surface. A series of steel casing pipes of gradually decreasing diameter will be cemented at certain depth intervals in order to: (1) maintain circulation of drilling fluids and to prevent contamination of ground waters; (2) prevent the hole from collapsing; and (3) present a clean surface to geothermal fluids. Wells drilled as production wells will consist of 20-inch, 13-3/8-inch, and 9-5/8-inch diameter casings. The 20-inch diameter casing (known as the surface casing) provides hole stability and reduces the loss of drilling mud into fractures near the surface. The 13-/8-inch diameter casing (known as the intermediate casing) will extend from the surface down into the caprock (at approximately 2,000 feet), and 9-5/8-inch casing (known as the production casing) will extend from the surface to about 4,000 feet.

Prior to inserting each string of casing into the hole, the hole is thoroughly flushed and cleaned by circulating fluids. Once this is done, the casing is gradually lowered in the hole and cemented in place. A 7-inch perforated liner will be installed from the bottom of the 9-5/8-inch casing to the bottom of the well at approximately 7,000 feet. This slotted casing helps to maintain well integrity, but is not cemented in place to allow for production of the geothermal fluids into the well to be brought to the surface. All casings will be steel, joined with premium threaded couplings. Figure 3-6 is a diagram of a typical production well, and Appendix B is a drilling and completion program for a typical production well. Average drilling time for the wells will be approximately 45 days.

Directional drilling will need to be used during drilling operations to change or control the direction the drilling is proceeding. This expensive procedure is necessary because more than one well is to be drilled from each wellpad, and the bottom-hole location of each well must be far enough away from each of the other well production zones to avoid unwanted interference between wells. Directionally drilled wells are first drilled vertically to a selected depth and are then gradually deviated in specific directions using down-hole directional drilling equipment.

The following mitigation measures will be taken to ensure the integrity of the geothermal wells and to prevent blowouts:

- Use blowout prevention equipment that can rapidly choke off the flow of fluids from the well during drilling;
- Use conservative safety factors in designing wells and wellhead equipment;
- Install two strings of steel casing cemented in place from the surface into the reservoir caprock;
- Use premium grade casing materials and connections to strengthen the wellbore;
- Specify cement mixtures with high strength and insulating properties;
- Follow correct procedures during cementing of well casing;
- Inspect and test the wellhead equipment regularly; and
- Periodically survey the casing to inspect its condition;

3.2.1.4.Well Cleanout and Testing

Each production well will need to be cleaned out after drilling to ensure maximum well productivity. During initial clean out, each well will be vented vertically to remove dust and drilling debris. PGV has found from past experience from drilling at Puna that vertical venting is necessary for effective cleanout.

Diverting the flow from the wells to a separator or a rock muffler during cleanout would cause large and small particles and mud to accumulate in the equipment and interfere with the flow testing. An analysis of BACT for wellfield emissions was conducted for the previously proposed project, and this analysis confirmed that the application of chemical treatment during well cleanout was impractical, ineffective, and likely to produce adverse environmental consequences. Thus, BACT for well venting consists of limiting the duration of the event and scheduling venting for periods with wind speeds ≥4 m/s, meteorological conditions which can be expected to prevent the venting emissions from exceeding the proposed H_2S ambient air quality standard (see Section 3.9).

During this venting, which may last a total of approximately four hours, the H_2S emissions will be unabated. To minimize the amount of H_2S released to the atmosphere during well venting, PGV will implement a program to clean out wells thoroughly prior to ceasing drilling operations by circulating fluids for a longer period of time. PGV will provide proper notification of well venting as required.

Table 3-4 shows the anticipated concentration of H_2S and the other noncondensable gases which will be produced from the Puna geothermal reservoir.

After initial cleanout, the wells will be flow tested to determine the quality, flow, composition and pressure of the fluid and the capacity of the reservoir feeding the well. Each well is anticipated to have a flow rate of between 55,000 and 90,000 lb/hr of steam; 14,000 to 22,000 lb/hr brine; and 50 to 120 lb/hr H_2S. Table 3-5 shows the chemical composition of the

Table 3-4. Composite Noncondensable Gas Composition

Element	Observed Content in Steam[a] (ppmw)		Design Composition (ppmw)
CO_2	250	- 1,042	600
H_2S	800	- 1,300	1,300
NH_3[b]			-
Ar	6	- 13	-
N_2	10	- 700	50
CH_4[c]			-
He	<0.009		-
H_2	11	- 1,412	20
Total NCG	1,500	- 2,200	1,970

Composite data from three wells on the PGV site (KS-1, KS-1A, and KS-2) and the HGP-A well

(a)Wellhead pressure = 155 psig;
Wellhead temperature = 368°F
(b)Below detection limit (<1.5 ppm NH_3 in KS-1A)
(c)Below detection limit (<0.2 ppm CH_4 in KS-1A)

geothermal fluid (brine and steam) anticipated to be produced from the Puna geothermal reservoir. Connections for a portable H_2S chemical abatement unit (consisting of NaOH tanks, injection pumps and piping) will be provided in the steamline from the separator to the rock muffler to be used to abate H_2S emissions during well testing. The NaOH will be injected into the steam stream downstream of the separators.

Initially, well testing may require up to 20 days per well; however, testing durations are anticipated to decrease to 10 days or less as more wells are added and reservoir experience

Table 3-5. Composite Geothermal Fluid Chemical Composition

Element	Brine[a] (ppmw)			Steam Condensate[a] (ppmw)
Na	600	-	10,000	0.17
K	123	-	2,700	0.1
Ca	40	-	920	0.1
Mg	1	-	2	<0.1
Fe	<1	-	8.4	0.05
Mn	<1	-	8.5	-
B	4	-	11	<0.5
Br	40	-	80	-
I	<20			-
F	0.2	-	0.9	-
Li	1	-	9	<0.01
Cl	925	-	21,000	<2
NH	<0.01	-	0.10	0.12
SO_3[b]	9.2	-	24	13
Hg	<0.001	-	<0.05	-
As	0.09	-	0.4	<0.01
S[c]	5	-	100	-
Total Alkalinity	≤10			<10
HCO_3	0	-	18	0
CO_3	0			0
SiO_2	420	-	1,500	0.7
TSS	70			-
TDS[d]	2,500	-	35,000	15
pH	≤5	-	5.5	3.5
Conductivity (mhos/cm)	3,100	-	67,000	120
Density	1.03			-

Composite data from three wells on the PGV site (KS-1, KS-1A, and KS-2) and the HGP-A well.

[a]Wellhead pressure = 155 psig;
Wellhead temperature = 368°F
[b]Concentration high due to oxidation of $S^=$ to SO_4
[c]Concentration low due to oxidation of $S^=$ to SO_4
[d]TDS = Total Dissolved Solids

increases. Wells may be flowed continuously or intermittently during the test period. No more than one well will be tested at any one time at the PGV Project wellfield.

Wells that are reworked after commencing operation may also have to be vented vertically and flow tested. The venting will be performed under the same conditions and with the same precautions as after initial drilling. The duration of the flow testing may be less than 10 days, and the steam and gases will either be released through the rock muffler at the wellpad or the flow will be directed through the pipelines to the power plant. In either case, the flow will initially pass through a separator. If the testing is through the rock muffler, the portable abatement unit will be used to inject NaOH into the steamline from the wellhead to the rock muffler such that H_2S emissions are abated by 95 percent. If the flow is directed to the power plant, there will be no emissions due to flow testing of the reworked well.

3.2.1.5.Wellpad Equipment

Each wellpad will contain a wellhead piping subsystem. This system is shown in Figure 3-9. The subsystem begins downstream of the master shutoff valves at each wellhead and includes production, throttling, and isolation valves and instrumentation required for monitoring and control of each well. A rock catcher(rock particle separator) will be installed immediately downstream of each wellhead.

Flash separators, approximately 6 feet in diameter and 12 feet high, will be located in the wellfield. The separators will partition the two-phase flow to steam (approximately 80 percent) and brine (approximately 20 percent). The separators will

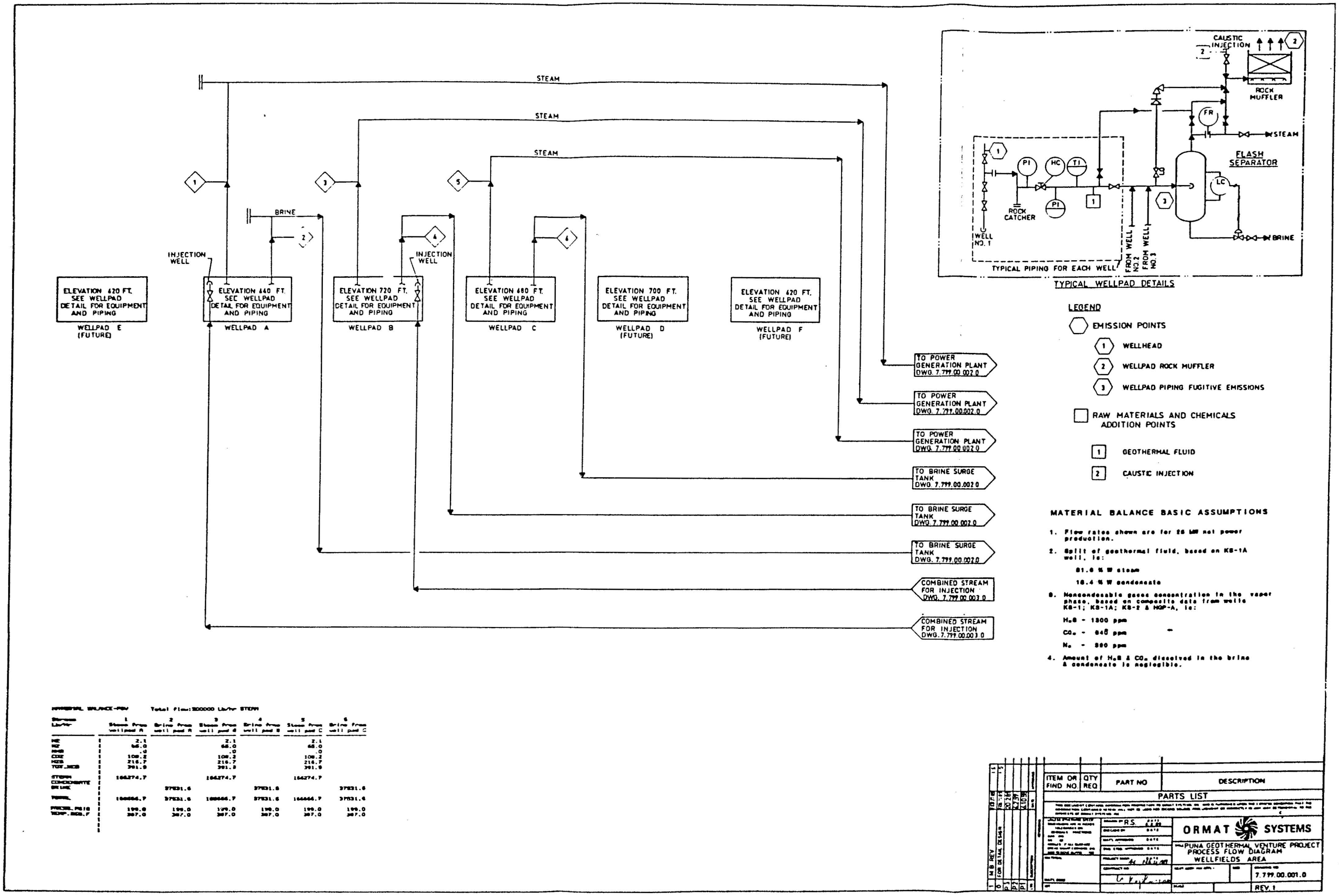


Figure 3-9

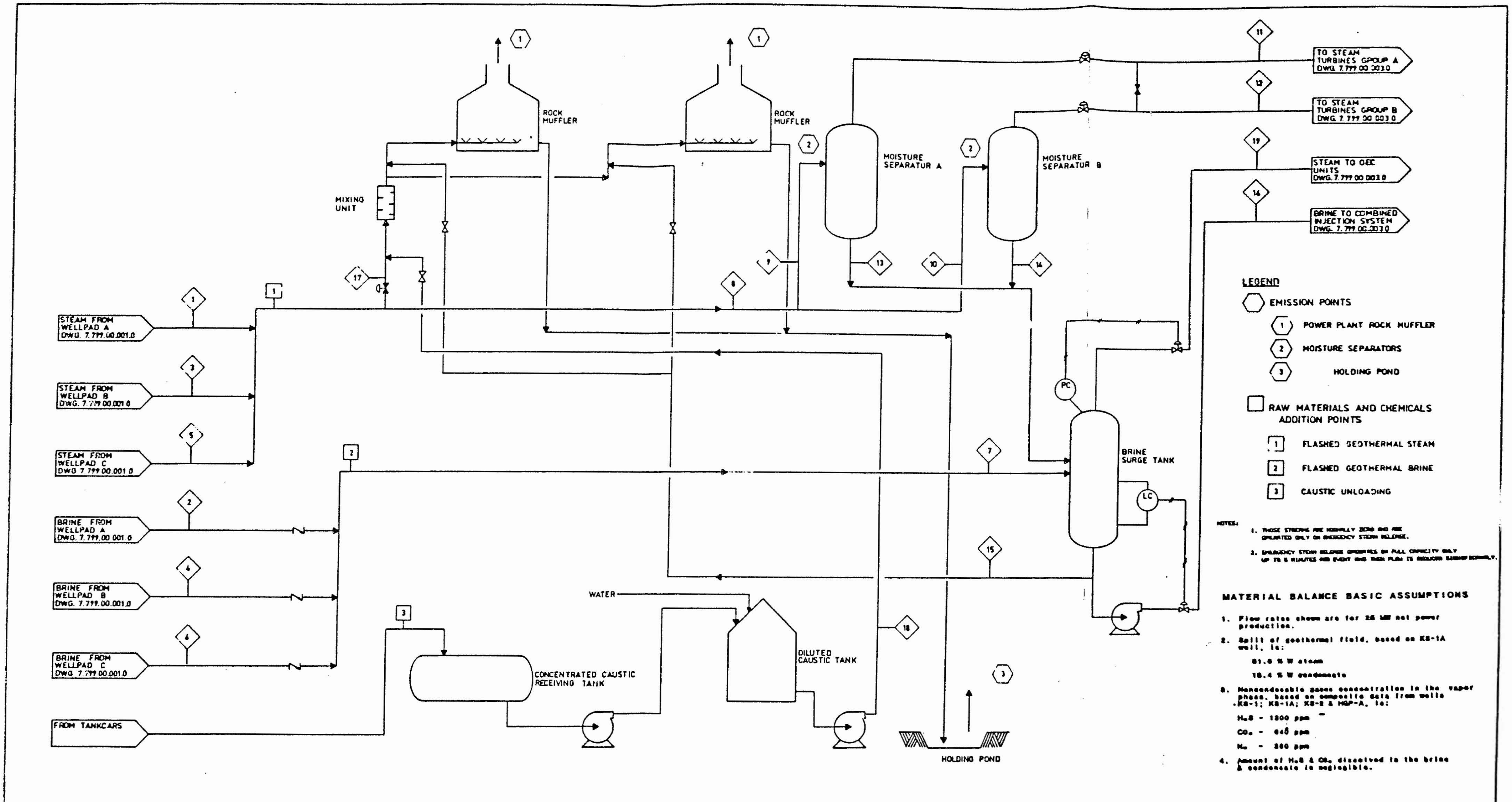
Figure 3-9. Wellfield Process Flow Diagram (Dwg. No. 7.799.00.001.0) operate at a pressure of approximately 200 psig. All wells will be equipped with temperature and pressure gauges. Flow from the wells will be measured, and operation of the flow control valves will be manual.

3.2.1.6.Wellfield Gathering Systems

Pipeline systems will collect each of the produced fluids and transport them to the power plant site. Up to three gathering systems will be required: steam, steam pipeline condensate and brine. Figure 3-10 is a process flow diagram of the gathering systems. Each gathering system will be independent of the other systems, interconnecting only at the points where two streams are present; for example, wellfield separators (steam and brine).

All pressure piping will be designed in accordance with the applicable American National Standards Institute (ANSI) codes and in conformance with Hawaii State codes. The piping systems are engineered for the stresses induced by thermal, pressure, dead, and seismic loads, taking into account all planned system operating conditions. Sufficient horizontal and vertical flexibility will be incorporated in the design to withstand ground movements in accordance with the Uniform Building Code (UBC) construction requirements for Seismic Zone 4. Seismic Zone 4 requirements will be incorporated in the design of the PGV Project as an extra safety precaution even though the Island of Hawaii is designated as an area requiring compliance only with the less stringent Seismic Zone 3 standards.

The external surfaces of the pipelines will be covered with insulation and painted in order to blend with the background



MATERIAL BALANCE-PGV Total Flow:500000 Lb/hr STEAM

Stream Lb/hr	1 Steam from wellpad A	2 Brine from well pad A	3 Steam from well pad B	4 Brine from well pad B	5 Steam from well pad C	6 Brine from well pad C	7 Combined brine	8 Combined steam	9 Steam to sep.A	10 Steam to sep.B
H2	2.1		2.1		2.1			6.2	3.2	3.2
N2	66.0		66.0		66.0			198.0	97.5	97.5
NH3	.0		.0		.0			0.1	.0	.0
CO2	108.2		108.2		108.2			324.4	162.2	162.2
H2S	216.7		216.7		216.7			650.0	325.0	325.0
TOT.NCG	391.8		391.9		391.8			1178.7	587.8	587.8
STEAM	166274.7		166274.7		166274.7		1122.1	497329.6	248664.8	248664.8
CONDENSATE								1494.6	747.3	747.3
BRINE		37531.6		37531.6		37531.6	111472.8			
TOTAL	166666.7	37531.6	166666.7	37531.6	166666.7	37531.6	112594.9	500000.0	250000.0	250000.0
PRESS.PSIG	199.0	199.0	199.0	199.0	199.0	199.0	183.0	191.0	191.0	191.0
TEMP.DEG.F	387.0	387.0	387.0	387.0	387.0	387.0	380.0	384.0	384.0	384.0

Stream Lb/hr	11 Steam to group A	12 Steam to group B	13 Cond.from sep.A	14 Cond.from sep.B	(1) 15 Brine to muffler	16 Brine to inj.system	(1)(2) 17 Steam rel. to muffler	(1)(2) 18 Diluted caustic	19 St.from srg. surge tank
H2	3.2	3.2					6.2		
N2	97.5	97.5					196.0		
NH3	.0	.0					0.1		
CO2	162.2	162.2					324.4		
H2S	325.0	325.0					650.0		
TOT.NCG	587.8	587.8					1178.7		
STEAM	248664.8	248664.8					497329.6		1930.2
CONDENSATE			747.3	747.3			1494.6		
BRINE					110664.8	112180.2			
TOTAL	249252.7	249252.7	747.3	747.3	110664.8	112180.2	500000.0	26315.0	1930.2
PRESS.PSIG	189.0	189.0	189.0	189.0	177.0	200.0	191.0	198.0	177.0
TEMP.DEG.F	383.0	383.0	383.0	383.0	376.0	378.0	384.0	77.0	376.0

ITEM OR FIND NO.	QTY REQ	PART NO.	DESCRIPTION

PARTS LIST

ORMAT SYSTEMS

PUNA GEOTHERMAL VENTURE PROJECT
PROCESS FLOW DIAGRAM
GATHERING SYSTEM

R.S

7.799.00.002.0

REV 1

Figure 3-10

Figure 3-10. Gathering System Process Flow Diagram (Dwg. No. 7.799.00.002.0) vegetation and/or volcanic rock and reduce visual impacts, consistent with safety concerns.

Approximately 3,000 feet of pipeline corridor will be needed to connect the six proposed wellpads to the power plant site. The pipelines will generally follow road alignments, wherever possible, to minimize the ground disturbance during installation and maintenance. This is also generally the shortest route from the source to the power plant, which minimizes the heat and frictional losses during transit. However, the pipeline layout may also be influenced by the terrain and the reduction of visual impacts. With a 10-foot wide corridor, ground disturbance for the 3,000 feet of pipelines will be less than 0.7 acres.

3.2.1.6.1.Steam Gathering System

Each steam/brine separator will discharge steam at approximately 200 psig into the steam gathering system. The steam gathering system will then transport the steam to the power plant. The steam gathering system starts out as a single line from each wellpad and which increases in diameter as the steam from other wellpads is connected together. Pipeline diameters will be 12 to 24 inches, depending upon both the amount of steam and the distance that the steam must be transported.

In addition to the pipes and valves involved in the system, the steam gathering system will include moisture separators at the power plant. These separators will remove any entrained water from the steam before entering the steam turbines. (Any water droplets carried into the turbines can cause increased wear on, or damage to, the turbine blades.)

The steam gathering system pipelines will be constructed of carbon steel. Allowances will be made for corrosion and other forms of long-term degradation of the carbon steel pipes. The pipelines will be insulated to conserve as much heat as possible since heat loss leads to condensation of part of the steam and reduces thermal energy and power production.
Steam gathering system pipelines will typically be supported from 2 to 4 feet above the ground. Actual heights will be determined by the terrain and other pipeline design considerations. Steel pillars with concrete foundations will support the pipelines at appropriate distances to prevent sagging. Thermal expansion of the pipe requires that expansion loops be used to prevent damage to the pipes. These loops will be kept horizontal as much as possible, but some vertical loops will be used, such as at road crossings.

Prior to start-up of the plant, the steam gathering system must be cleaned out to prevent dirt and debris from entering the power plant equipment. Cleanout is accomplished by passing the steam from one or more wells through the pipeline and venting it unabated directly to the atmosphere. As with initial cleanout of the wells, it is not practical or desireable to use chemical abatement during pipeline cleanouts, and therefore, pipeline cleanouts will be scheduled during periods when wind speed $\geq$4 m/s, conditions which will provide for maintenance of the H_2S ambient air quality standard. Cleanout will also be scheduled so that it will not coincide with well venting, flow testing, or drilling with aerated water or mud.

3.2.1.6.2. Steam Pipeline Condensate Gathering System

Depending on terrain and distance, a steam pipeline condensate gathering system may be needed to collect steam that condenses in the steam gathering pipelines. If a steam condensate pipeline is installed, drains at the low points of the steam gathering line would allow the condensate from the steam pipelines to enter the condensate gathering system.

The steam condensate gathering system pipelines, if installed, would also be constructed of carbon steel but would be much smaller in diameter (probably 2 inches) than the steam gathering system pipelines. Allowances would also be made for corrosion and other forms of long-term degradation of the pipes.

The steam condensate pipeline would transfer the collected condensate under pressure to a steam line at the outlet of the steam turbines. In general, the condensate gathering system, if necessary, would parallel the steam gathering system.

3.2.1.6.3. Brine Gathering System

The brine gathering system will transport the brine under pressure from the wellfield separators to the brine surge tank, located at the power plant site. From there, the brine would flow to the injection wells, where all geothermal fluids produced during operation of the PGV Project wellfield and power plant (geothermal brine, geothermal steam condensate, and geothermal noncondensable gases) will be combined and injected back into the geothermal reservoir. The pipelines used in the brine gathering system will be 4 to 6 inches in diameter, smaller than the steam gathering pipelines.

The brine gathering system will follow the same corridors as the steam gathering system, and will consist of carbon steel pipelines insulated to maintain heat and painted to blend with the vegetation.

3.2.1.7.Geothermal Fluids Injection System

Under normal operating conditions, essentially all geothermal fluids produced during operation of the PGV Project wellfield and power plant (geothermal brine, geothermal steam condensate, and geothermal noncondensable gases) will be injected back into the geothermal reservoir and only negligible fugitive emissions of the geothermal fluids might be expected.

Recombining of all the geothermal components will probably be in the following sequence: first, the condensate will be cooled and combined with the brine; second, the compressed noncondensable gases will be mixed with the combined condensate and brine to produce one geothermal fluid, which will have basically the same composition as the original geothermal fluid.

PGV anticipates that all three geothermal streams will be combined into one (1) stream and injected into one (1) well, but depending upon the chemical behavior of the combined stream, there is a possibility that brine and condensate will be injected in two (2) separate wells. This decision will be made prior to power plant operation.

Wells will likely be drilled specifically for the injection of the geothermal fluids (see Section 3.2.1.1). Alternatively, marginal geothermal production wells, which are production wells producing less-than-desired steam flow or steam fraction and, therefore, are not economical to use in producing electrical energy, may be used as injection wells. Wells drilled specifically for injection would still be drilled into the geothermal reservoir, but would likely be more shallow than wells drilled as geothermal production wells. This would still ensure reliable, safe injection of the geothermal fluids back into the geothermal reservoir, and would possibly reduce the cost of the well through, as shown in Figure 3-11, the elimination of the intermediate string of casing from the well design. In either event, hang-down strings of special or coated solid steel liners would be used to protect the premium casing of each well during its use as an injection well. These removable strings of pipe will be placed inside the larger diameter casing. Up to three injection wells (two operating plus a spare) will be required to inject the maximum anticipated 570,000 lb/hr (1,140 gpm) of produced geothermal fluids (see Section 3.2.2).

The required well drilling and/or conversion permits will be obtained from the Department of Land and Natural Resources (DLNR), as necessary.

To ensure high reliability of the geothermal fluids injection system, each component of the system will be backed by a spare. A spare fluid pump, a spare noncondensable gas compressor, and a spare geothermal injection well will be provided. However, in the unlikely event of an upset in the injection system, an unlined holding pond will be constructed at the power plant site to receive, and temporarily store until it infiltrates, geothermal brine and/or condensate (see also Section 3.2.2.3). Prior to discharge to the holding pond, the brine will pass through the emergency steam facility and a small amount of steam

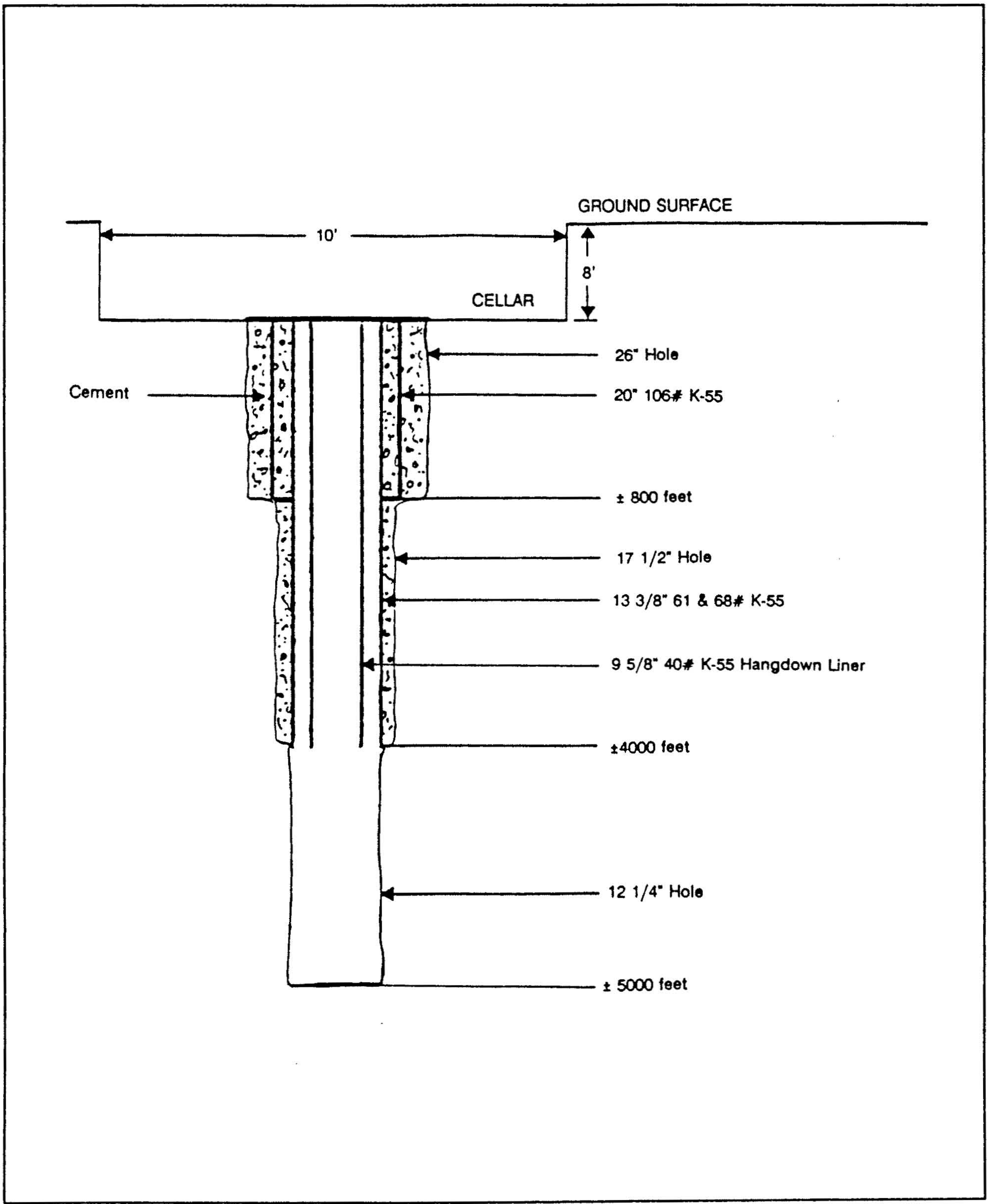


Figure 3-11. Typical Injection Well Design

and H_2S would be released through the rock muffler.

3.2.1.8. Makeup Wells

Over the lifetime of the project, individual geothermal wells may require to be supplemented or replaced because production or injection capability has declined to a point where the well's contribution to the project is minimal. As many as 20 wells may be drilled over the 35-year economic life of the project to maintain full plant output (see Section 3.2.1.1 and Section 3.2.1.3). Wells no longer useful for production or injection may be used for reservoir monitoring or abandoned (see Section 3.2.7).

3.2.2. Power Production Systems

The PGV Project power plant is designed to provide approximately 25 MW of capacity to the HELCO energy grid system. The power plant will be built with a maximum gross capacity of approximately 28.5 MW, with the difference being used by the power plant for internal energy requirements. Actual ambient temperatures and other operating conditions will vary the amount of electricity generated and/or steam required, with more power able to be generated during periods of cooler air temperatures.

The PGV Project power plant will consist of ten modules, each one consisting of a back-pressure steam turbine integrated in series with an air-cooled binary cycle OEC unit, so that steam leaving each steam turbine is utilized in the vaporizer of the companion binary OEC unit. A flow diagram of the power plant, showing a general heat and mass balance, is presented in Figure 3-12. Under normal operating conditions, an estimated 500,000 lb/hr of steam (at 381°F and 184 psig) at the steam turbine inlet will be required to generate the full 25 MW (net) of power, but up to 570,000 lb/hr of steam may be required, depending on actual reservoir conditions encountered (pressure and temperature).

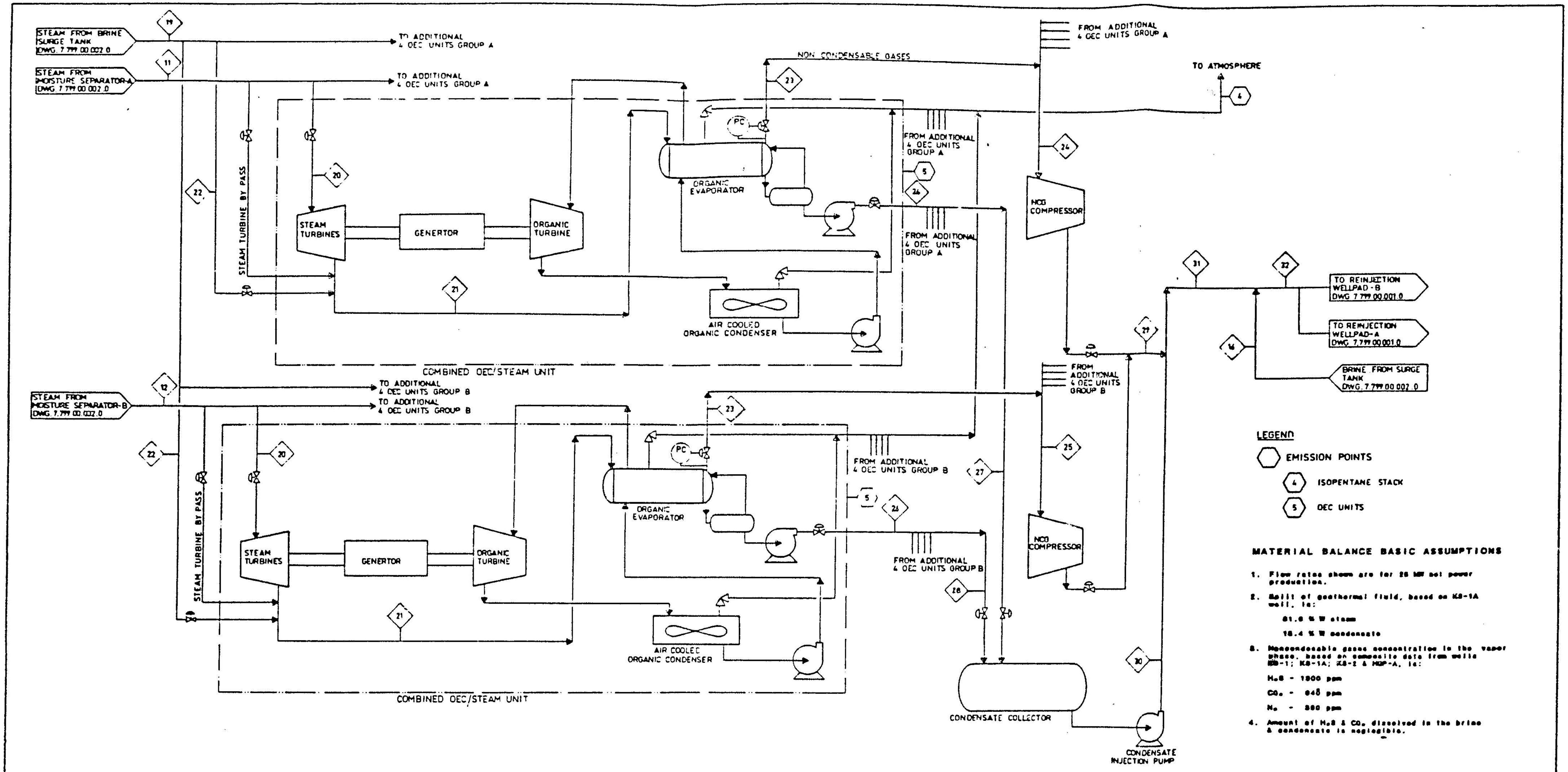
The power generation equipment will occupy the 6-acre power plant site at an elevation of approximately 670 feet AMSL between Wellpads A and B. Figure 3-13 shows the general arrangement of the power plant site. The steam turbine\air-cooled OEC unit modules will be arranged in two parallel banks in the middle of the plant site. All of the auxiliary equipment will be located on the power plant site, except the holding pond and rock mufflers which will be located south of the southeastern corner of the site (see Section 3.2.2.3).

3.2.2.1.Turbine-Generator System

3.2.2.1.1.Steam Turbines

The steam turbines operate by removing the heat energy from the steam and converting it into mechanical work. As the steam expands through each turbine, it increases its velocity. The high-velocity steam pushes against a series of blades in the turbine and rotates the blades. The blades are connected to a central shaft which rotates the generator, which generates the electrical energy.

High-pressure steam at approximately 381°F and 184 psig will be delivered during normal operation and average conditions to the inlet of each steam turbine. After driving the steam turbine, the steam will exit at a pressure still above atmospheric. (Because the steam exits these turbines at a pressure above



MATERIAL BALANCE - PGV   Total Flow: 500000 Lb/hr STEAM

Stream Lb/hr	11 Steam to group A	12 Steam to group B	16 Brine to inj. system	20 St. to st. turb. unit	21 Steam to OEC unit	22 Brn. flash to st. turb. unit	23 NCG from OEC unit	24 NCG from OEC group A	25 NCG from OEC group B	26 Cond. from OEC evap.	27 Cond. from OEC group A	28 Cond. from OEC group B	29 Comp. NCG from cond	30 Comb. cond. from wells	31 Con. & NCG stream	32 Combined inject. str.
H2	3.2	3.2		0.6	0.6		0.6	3.1	3.1				6.2		5.2	6.2
N2	97.5	97.5		19.5	19.5		19.5	97.5	97.5				196.0		196.0	196.0
NH3	.0	.0		.0	.0		.0	.0	.0				0.1		0.1	0.1
CO2	162.2	162.2		32.4	32.4		32.4	162.2	162.2				324.4		324.4	324.4
H2S	325.0	325.0		65.0	65.0		65.0	325.0	325.0				650.0		650.0	650.0
TOT. NCG	587.8	587.8		117.6	117.6		117.5	587.8	587.8				1175.7		1175.7	1175.7
STEAM	248644.9	248644.0		49732.9	49925.9	193.0	176.4	881.8	881.8				1763.6			
CONDENSATE										49675.3	240301.9	240301.5		496763.1	498526.6	498526.6
BRINE			112189.2													112189.2
TOTAL	249252.7	249252.7	112189.2	49850.5	50043.5	193.0	293.9	1469.6	1469.6	49675.3	240301.5	240301.5	2939.2	496763.1	499702.3	611061.8
PRESS. PSIG	189.0	189.0	200.0	184.0	11.0	177.0	10.0	10.0	10.0	10.0	10.0	10.0	200.0	200.0	200.0	200.0
TEMP. DEG. F	383.0	383.0	370.0	381.0	240.0	376.0	230.0	230.0	230.0	230.0	230.0	230.0	330.0	236.0	240.0	265.0

ITEM OR FIND NO.	QTY REQ	PART NO	DESCRIPTION

PARTS LIST

ORMAT SYSTEMS

PUNA GEOTHERMAL VENTURE PROJECT
PROCESS FLOW DIAGRAM
POWEP GENERATION AREA

7.799.00.003.0

REV 1

Figure 3-12

Figure 3-12. Power Generation Area Process Flow Diagram (Dwg. No. 7.799.00.003.0)

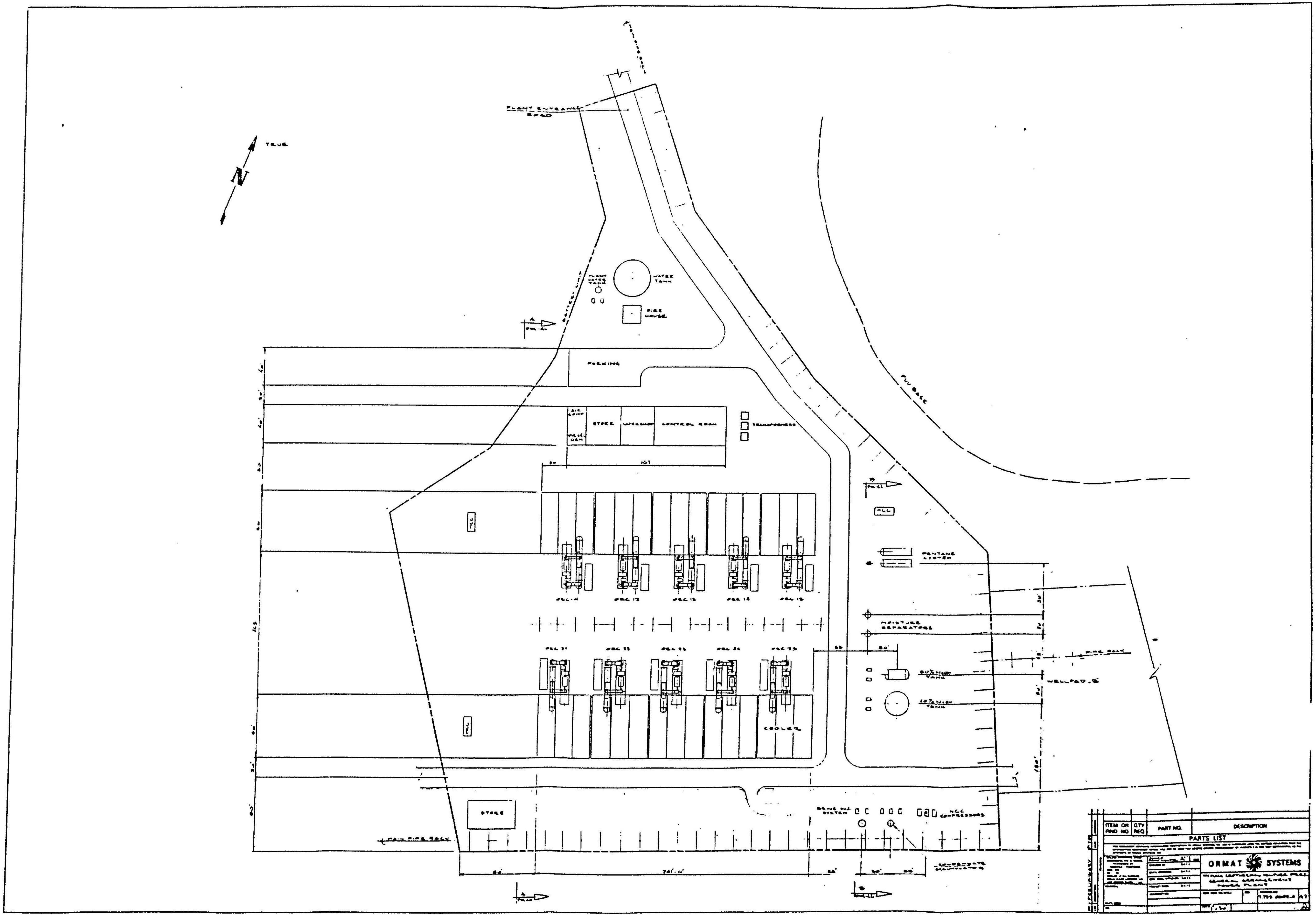


Figure 3-13

Figure 3-13. Power Plant General Arrangement (Dwg. No. 7.799.00.102.0) atmospheric levels, these turbines are called back-pressure steam turbines.) The low-pressure steam leaving each turbine will be routed to the companion OEC binary unit.

Turbine control and isolation will be provided by control and stop valves in the main steamline, positioned just upstream of the turbines. The turbines will include auxiliary systems (such as lubrication, shaft sealing and cooling) necessary for turbine operation.

3.2.2.1.2.Steam Turbine Bypass

Each steam turbine will be equipped with a bypass system which is designed to direct the high pressure steam around the steam turbine directly to the OEC binary unit.

During turbine upset conditions or start-up, the steam turbine bypass system will route the steam around the effected turbine directly to its corresponding OEC unit. The steam turbine bypass system will allow a generator to operate, in a reduced capacity, while the connected steam turbine is off-line. When a steam turbine bypass system is actuated, the steam turbine bypass valves are opened and the OEC unit, which is capable of operating with high temperature steam, will continue to operate. The steam flow from the wells will be reduced as necessary to accommodate the reduced production capacity of the power plant.

3.2.2.1.3.OEC Binary Units

The low-pressure steam exiting each steam turbine will flow through steam piping to its corresponding 1.2 MW air-cooled OEC binary unit. Each OEC unit is a self-contained generating unit.

Major components of an OEC unit are: a working fluid vaporizer, a turbine, an air-cooled working fluid condenser, and a working fluid recycle pump. The OEC modules will also include automatic and manual control valves, level switches, pressure gauges, pressure controls, internal piping, and power and control boards.

The OEC unit system is based on the Rankine power cycle. The cycle will use isopentane as the working fluid for this project. Isopentane is a colorless hydrocarbon liquid, much like butane or propane (bottled gas), but is much less hazardous because it has a much lower vapor pressure (see Section 3.2.3.5). A schematic flow diagram of the OEC cycle is shown in Figure 3-14. Approximately 298,000 lb/hr of 136°F isopentane working fluid will be vaporized by the heat of the low-pressure geothermal steam flowing through each vaporizer. The resulting 214°F isopentane vapor will expand as it passes through the impulse turbine, which is coupled to a generator that produces 3-phase electrical power. The exhaust vapor is condensed in an air-cooled condenser and recycled to the vaporizer by the working fluid recycle pump. The condensed steam from the vaporizer will be mixed with the brine and the noncondensable gases and then injected into the geothermal reservoir (see Section 3.2.1.7).

The OEC unit vaporizers will be shell-and-tube type heat exchangers designed and fabricated in accordance with the applicable TEMA-C standards and ASME codes (Unfired Pressure Vessels, Section VII, Div. I). Vaporization of the working fluid will take place in the shell side of the heat exchangers, while the low-pressure geothermal steam will flow inside the tubes to facilitate cleaning of the heat exchangers. A liquid separator installed at the outlet of the vaporizer will prevent liquid isopentane droplets from being entrained in the vapor and

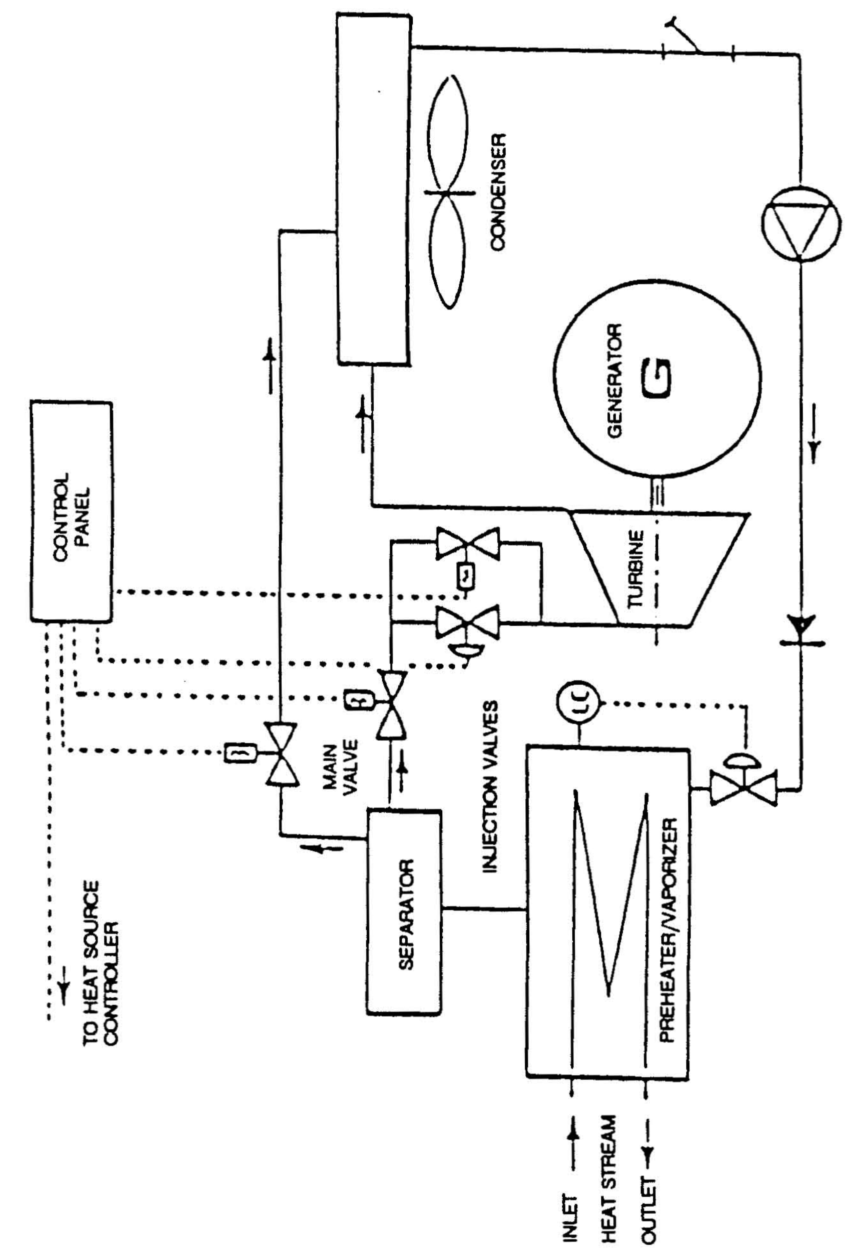


Figure 3-14. Ormat Energy Converter Unit Schematic Flow Chart

subsequently impinging on the turbine impeller blades. The OEC turbines will have injection nozzles and turbine blades specifically designed to operate with organic vapor. The injection valves will be designed to operate at high efficiencies over a wide range of process conditions.

After passing through the turbine, the vaporized working fluid will be routed to an air cooling unit, the top of which is elevated approximately 24 feet above ground level. Vertically mounted fans will force air across the condenser vapor tubes, removing sufficient heat to condense the working liquid. The condensed isopentane will accumulate at the feed pump suction inlet by gravity flow. The air coolers will be sited adjacent to the OEC unit turbine-generator and vaporizer as shown in Figure 3-13. The propeller fans for each set of air coolers will be driven by electric motors by means of a positive drive belt. Air cooling will completely eliminate the drift, gaseous emissions, water requirements, and liquid blowdown associated with water cooling towers.

The cycle feed pump, controlled by a level control device, will pump the working fluid to the vaporizer. The motor-driven pump is a multi-stage centrifugal pump with mechanical seals and is characterized by overall high efficiency and low net positive suction head.

The OEC units will be equipped with pneumatic valves to regulate the flows of vapor and liquid in the organic fluid cycle. All valves will be designed and constructed in accordance with the ANSI Class 150 or 300, as appropriate. The OEC units will also have an internal bypass to divert the isopentane vapor directly to the air coolers in case of malfunctioning of the turbine or the generator.

Operation of the power plant will result in some fugitive isopentane emissions. Mechanical seals on each OEC unit are designed and manufactured as per API 610 specifications, and fugitive emissions from the mechanical seals on each OEC unit will be only about 60 gallons per year, or less than 0.032 lb/hr. Negligible emissions of isopentane to the atmosphere may occur from other minor system leaks during normal operations. Fugitive isopentane emissions will not exceed 0.4 lb/hr total from all OECs. Maximum isopentane concentrations will not exceed 1000 ppm from any seal, flange, valve or other fugitive emissions point, when measured from a distance of 2 inches (5 cm) from the point.

Upset operational emissions of isopentane to the atmosphere could occur upon activation of any of the isopentane pressure relief valves (of which there are two on each OEC unit) or upon certain other unlikely equipment upsets. However, because each of the OEC units are independent modules, the amount and duration of any such release will be limited. The release point will be from a 32-foot stack at one of the ends of the air cooler for each OEC unit, and dispersion will be enhanced by the action of the air cooler fans.

Should an overpressure situation arise in an OEC unit, an alarm will be activated, and the unit will be shut down automatically. The maximum release from an individual OEC unit is expected to be 2,500 lb, one-third of the contents of an OEC unit. Typically, after only a few seconds, the pressure in the working cycle is expected to drop, and the relief valve will close.

3.2.2.1.4. Generators

Each steam turbine and OEC turbine will be connected to a common 3,600 rpm, 13.8 kV electric generator. The generators convert the mechanical energy of the turbines into 3-phase electrical power. The 13.8 kV generators will be cooled by air. Protective devices will guard against overcurrent, overvoltage, loss of field, and fluctuation in frequency. Dedicated power circuit breakers will serve each generator.

3.2.2.2. Noncondensable Gas Control

Under normal operating conditions, there will be no emissions of H_2S other than negligible fugitive emissions from piping joints, which will be minimized through proper design, ongoing maintenance procedures and monitoring by plant operators. All other noncondensable gases produced at the wells will be injected back into the geothermal reservoir.

Almost all of the noncondensable gases produced from the geothermal reservoir with the geothermal fluids will be partitioned with the steam in the flash separators and will pass through the steam turbines. As the low-pressure steam leaving the steam turbines is condensed in the OEC vaporizers, the noncondensable gases and residual water vapor will remain under low pressure. With the design composition of the noncondensable gases in the Puna Geothermal field, an estimated 650 lb/hr H_2S and 324 lb/hr CO_2 will be passed through the ten (10) OEC unit vaporizers. These gases will be piped from the vaporizers of the OEC units to gas compressors, which will compress the gases prior to injection into the combined steam condensate and brine line and, ultimately, will be injected into the geothermal reservoir (see Section 3.2.1.7).

Dissolving H_2S and/or CO_2 into water is a well-known operation in the field of chemical engineering. The abatement of H_2S and CO_2 emissions by gas injection, as described above, has been demonstrated successful at the Coso geothermal reservoir in California since July, 1987. Gas injection has the advantage of not only controlling H_2S, but also abating other produced noncondensable gases, including the emission of CO_2. (CO_2 is the gas considered most responsible for the "greenhouse effect," the accelerated warming of the earth's atmosphere due to increased absorption of infrared radiation.)

During start-up and extended periods of operation below 50 percent of rated capacity, water may be needed to maintain injection flow and to provide a sufficient quantity of fluid to absorb the noncondensable gases. Maximum requirements are estimated at 500 gallons per minute, which could be supplied by one or two wells developed near the plant site. PGV is still evaluating the need for this supplementary water, which will depend on the final design of the injection system. No additional water will be needed during normal operation.

To ensure high reliability of the geothermal fluids injection system, each major component of the system will be backed by a spare. A spare fluid pump, a spare noncondensable gases compressor, and a spare geothermal injection well will be provided. However, in the unlikely event of an upset in the injection system, the brine will pass through the rock mufflers, where it will be flashed, and then sent to the holding pond. Complete failure of the injection system would cause the entire power plant to go off line, and steam would be released through the steam release facility. Since the brine will be routed through the other rock muffler at atmospheric pressure, the gases released from the brine can be treated, and negligible H_2S emissions are expected from the holding pond.

3.2.2.3. Steam Release Facility

The steam release facility will be used to release steam and treated noncondensable gases to the atmosphere under certain relatively uncommon upset conditions. Under most upset conditions of the power plant generating units, such as a steam turbine trip or OEC unit failure, the steam flow from the wellfield (reduced as necessary) will bypass the effected unit or units and the remainder of the steam turbines and OEC units will continue operating (see Section 3.2.2.1.2). Only if there were a failure of the electrical transmission line(s) out of the power plant (or some incident, such as an electrical outage, occurred that tripped all the steam turbines and the OEC units), or there were a complete upset of the geothermal fluid injection system (which is extremely unlikely, for all the reasons presented in Section 3.2.1.7), or if pressure in the steam lines exceeded design set points (which would release excess steam through safety relief valves) would steam be released through the steam release facility. Over a period of up to four (4) hours, the flow from the geothermal wells would be reduced gradually to about fifty (50) percent, the minimum flow determined appropriate to maintain well temperatures. After reduction, not more than about 285,000 lb/hr steam (fifty (50) percent of full flow) would continue to be released through the steam release facility until the power plant could recommence operations.

The steam release facility will consist principally of two rock mufflers installed near the power plant site. The rock mufflers will be constructed of heat-resistant reinforced concrete or other appropriate material and filled with lava rock. The mufflers are designed to dissipate the steam's acoustic energy, thereby reducing the noise associated with a steam release. Each muffler will be designed to handle 570,000 lb/hr steam, which is 100 percent of the maximum total plant steam flow. (If the valves to the emergency steam release facility failed to operate, the steam would be released through relief valves in the steam gathering lines, which will be set at slightly higher pressure points.)

Prior to entering the steam release facility, the steam will be treated with NaOH and water to remove the majority of the H_2S. The effective reactions are:

$$H_2S + NaOH \leftrightarrow NaHS + H_2O$$
$$H_2S + 2NaOH \leftrightarrow Na_2S + 2H_2O$$

Based upon state-of-the art rock muffler design and current experience, 96 percent removal of the H_2S is anticipated from the NaOH treatment system. After the 50-percent reduction in steam flow, effective H_2S control will be 98 percent. Storage tanks will be provided at the power plant site for the NaOH. Injection pumps will meter the NaOH injected into the steam line.

3.2.2.4.Electrical Systems

The power plant will contain several electrical systems. The major electrical equipment includes the main power, auxiliary, station service, and current and potential transformers;

generator circuit breakers; high-voltage switchgear; load centers; motor control centers; and station batteries.

The power from each 13.8 kV generator will be fed to the 13.8 kV busbars, with a switchgear for each generator. Each 13.8 kV busbar will be connected to a 13.8/69 kV step-up transformer and power will be fed into the HELCO switching and metering yard at a voltage of 69 kV. The 13.8 kV/480 V step down transformers will supply 480 V power for all the power plant internal requirements and for the auxiliary systems.

A 250 kW diesel-generator unit will be installed at the plant site to produce power for essential electrical services at the PGV site under emergency conditions, if needed, as well as to enable cold start-up of one OEC unit without external power. The power that would be generated from the diesel-generator would be sufficient to cold start-up and, at the same time, support one air compressor; the battery chargers; the heating, ventilating, and air conditioning (HVAC) system; control room systems; steam release facility H_2S abatement system; and emergency lighting. The 250 kW standby generator is not expected to operate more than 50 hours a year, based on two 24-hour transmission line outages. This estimate assumes that at least one steam turbine/OEC module will be able to operate under other steam release situations.

3.2.2.5.Control Systems

The control system consists of three control subsystems:

- The wellhead control subsystem;

- The OEC control subsystem; and

- The power plant control subsystem.

3.2.2.5.1.Wellhead Control Subsystem

The wellhead control subsystem includes the individual wellheads, the wellpads, the gathering systems and the emergency steam release facility.

All wellheads will be equipped with temperature and pressure gauges on the well casing below the master valves. Flow from each wellhead will be regulated manually. The steam flow leaving each wellpad will be measured. Control valves at the steam release facility will have air-piston operators that respond automatically to signals from the plant control room or upon sensing over-pressure in the steam pipeline. The H_2S abatement system at the steam release facility will operate automatically when steam is released through the rock mufflers.

3.2.2.5.2.OEC Control Subsystem

The OEC control, housed in an individual OEC control shelter located adjacent to each OEC module, will control both the steam turbines and the OEC units.

A programmable controller will be used to record, process, and signal steam and working fluid pressures, voltage levels, speed, kilowatt output, and current of each OEC unit as well as its steam turbine unit. The programmable controller provides diagnostic as well as control functions and will allow the operator to isolate an individual unit for testing or repairs and then automatically restart it after the failure condition has been rectified.

The individual OEC control shed will also house the high power, high voltage components of the OEC units including the circuit breakers, magnetic contacts, fuses, transformers, power capacitors, metering instruments, overload, short circuit asymmetry, and reverse power protective devices.

3.2.2.5.3. Power Plant Control

The entire power plant is designed with a computerized automatic control system that will require a minimum number of personnel to operate the plant. The plant operators will monitor the plant during operation from the main control room, with regular onsite monitoring of all equipment. Individual and plant-wide control systems will operate automatically to prevent injuries to plant personnel or equipment and to protect public health and safety. Standby equipment will start automatically to avoid tripping a turbine unit during normal operations. Monitoring data will be logged and stored in the programmable controller. Information and control signals from the individual OEC controllers will be recorded and controlled from the main power plant control room.

3.2.2.6. Auxiliary Systems

The primary auxiliary systems will be the compressed air system, HVAC system, service water system, and fire protection system.

3.2.2.6.1.Compressed Air System

Compressed air is required for instrumentation, control, and plant maintenance (service air) requirements. Compressed air at 100 psig is distributed throughout the plant from a central compression system that includes air compressors, desiccant-type dryers, and dry-air storage tanks.

3.2.2.6.2.HVAC Systems

Air conditioning will be provided for the electrical equipment and control room. The system will be designed to prevent heat buildup and maintain a positive pressure in the rooms. The air conditioning will include a sealed refrigeration system and coil, outside air supply duct, and an air distribution fan.

3.2.2.6.3.Fire Protection System

The fire protection system will be designed in accordance with applicable National Fire Protection Association (NFPA) and Hawaii State standards and will include the following:

- Fire protection water supplies, pumps and controllers, yard mains, hydrants, and valves.

- An automatic wet pipe and fusible link sprinkler system or CO_2 or Halon equipment in the control room.

- Automatic fire protection system for electrical systems.

- Portable extinguishers with backup water hoses in the control room.

A water tank will be the primary source of water for fire suppression. The volume of the storage tank will be adequate for storing the quantity required according to local regulations, NFPA standards and insurance company requirements. The 315 hp firewater pumps will be diesel driven. Hose stations will be strategically positioned in the plant.

The control room, motor control center, and electrical equipment rooms will be protected with an automatic fire protection system. CO_2 or Halon fire extinguishing equipment may be used in these areas to prevent water damage. If CO_2 is selected, water hoses would also be installed in the event that the CO_2 fails to extinguish the fire. Portable extinguishers will also be provided in the control room.

3.2.2.6.4. Service and Supplemental Water

Service water will be used for general purpose cleaning and maintenance of the power plant. A 2,000-gallon (approximately) tank will provide the service water for the facility.

Supplemental water may need to be added to the fluid injection system during periods of operation at low-load or during start-up to ensure maintenance of the water column in the injection system, which is necessary for proper operation of the gas control system. Up to 500 gpm will be obtained from one or two onsite wells, drawing water from the geothermally influenced groundwater below 600 feet.

3.2.3. Power Plant Structures and Facilities

3.2.3.1. Buildings

There will be one main building for the central control room, offices, warehouse, workshop, air compression system and the emergency generator (see Figure 3-13 and Figure 3-15). The structural steel side walls and roof framing are covered with metal siding and roofing. The structure will be painted to blend with the surrounding area. In addition, there will be ten shelters for the OEC units and another storage shed for the heavy equipment.

3.2.3.2. Structural Design

All major structures are of steel frame construction. The structures and major equipment rest on footings. Minor equipment is placed on slab floors or mounted on walls. Anchors will secure all equipment to foundations, mounting pads, or surfaces. All major structures, foundations, and footings will be designed to support all applicable loads and will be designed for Seismic Zone 4 requirements.

3.2.3.3. Foundation Design

The steam turbines reinforced-concrete, OEC units, and air coolers will each sit on reinforced-concrete foundations. The outdoor electrical transformers will be mounted on concrete foundations.

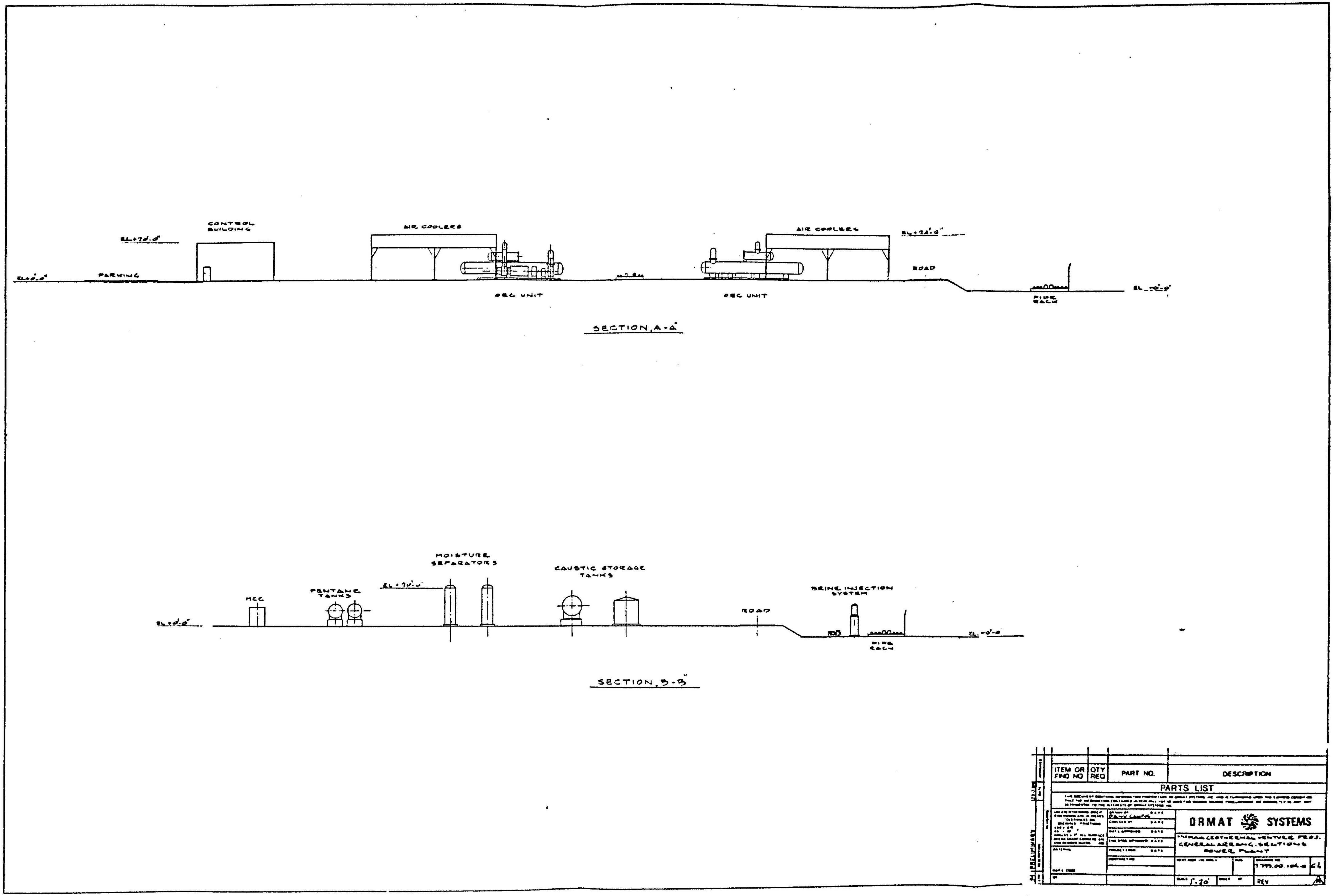


Figure 3-15

Figure 3-15. Preliminary Elevation Drawings of the Power Plant (Dwg. No. 7.799.00.104.0)

3.2.3.4. Site Drainage Facilities

The high porosity of the volcanic soils and rock in the site area results in rapid downward percolation of rainwater. Concrete pads and berms are provided to contain possible spills in areas where chemicals are handled. Catch basins, culverts, ditches, and berms are provided for drainage control where necessary.

3.2.3.5. Chemical Storage Facilities

The only hazardous chemicals used in significant quantities will be isopentane and caustic soda (NaOH).

Isopentane is a colorless liquid that vaporizes at 82°F. It is not toxic or corrosive, but is flammable at concentrations between 1.4 percent and 8.0 percent (volume) in air. Isopentane is similar to propane (bottled gas), which is used for heating and cooking in many rural locations, but is much less hazardous than propane because of its higher boiling point and lower vapor pressure.

Each OEC unit will contain approximately 7,500 pounds of isopentane. Additional isopentane, as much as 10,000 pounds, will be stored onsite in two tanks which also have sufficient capacity to receive the entire isopentane contents of an OEC unit. The tanks will have a design temperature of 250°F and design pressure of 150 psig. Working fluid pumps will be used to transfer isopentane to and from the tanks to recharge the systems or remove the isopentane from OEC units requiring maintenance.

To reduce the possibility of isopentane presence in flammable concentrations at ground level due to release from one or more of the safety relief valves located at the OEC heat exchangers, each relief valve is furnished with a pipe, releasing to the atmosphere eight (8) feet above the air coolers, which is the highest point in the plant. This release height is in conformance with API and NFPA safety standards for this gas.

Caustic soda (NaOH) is a corrosive material that is toxic if ingested and can cause skin and eye irritation upon contact. It is soluble in water and used in households as a cleaning agent. NaOH will be delivered to the site as a 50-percent solution and stored in two tanks: one with a 50-percent solution as delivered, and the other with a 10-percent solution, diluted for use in the abatement system.

Secondary containment structures such as dikes or berms will be constructed around the NaOH storage tanks. These tanks will be segregated by distance from any incompatible materials. Applicable federal regulations (e.g. OSHA and EPA) and Hawaii regulations (e.g. DOSH and DOH) will be incorporated into procedures and standard policies of the facility. Applicable Department of Transportation (DOT) regulations (Title 49 CFR, Sections 171-178) will be incorporated into the procedures for delivery of any hazardous materials used on site.

3.2.3.6. Fencing

A six-foot-high chain-link fence will be installed around the power plant site boundary and each of the wellpads. A gate at each entrance to the sites will restrict unauthorized access.

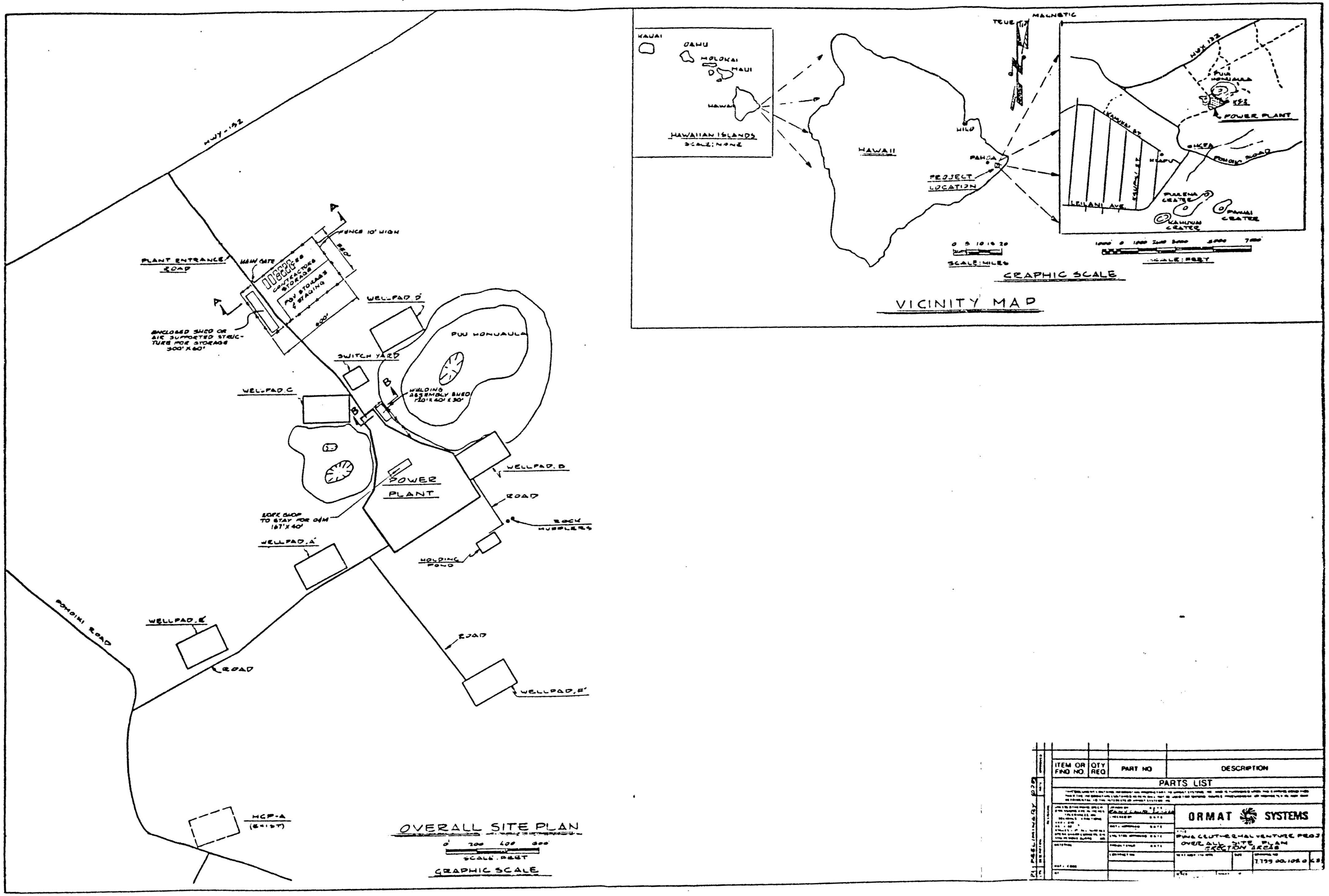
3.2.4. Construction

Site construction presents employment opportunities for skilled and unskilled labor. An average of approximately 23 people will be needed throughout the construction period. Estimated peak construction employment at the site is expected to be 100 persons. Most of the construction work is anticipated to be accomplished by local contractors and the local labor force. Site construction activities (other than geothermal well drilling) will be restricted as much as possible to daylight hours.

A temporary construction yard of about 5 acres will be located next to the main entrance road to the plant, off Highway 132 (see Figure 3-16). The construction yard will be used for the temporary storage of construction materials and fabrication of some project components. The construction yard will be fenced and will contain several temporary structures (trailers, buildings and sheds).

Water will be used as necessary to control fugitive dust produced by construction activities. Dust is not expected to be a serious concern at Puna, which receives an average of 120 inches of rainfall a year.

Visual impacts created by construction of the project will be mitigated by use of low-contrast paint schemes and landscaping with native plants (see Section 3.3). Cut-and-fill slopes, as well as any uncovered level areas, will be seeded or planted with native vegetation when construction is complete. Landscaping will be performed around the wellpad and power plant, and paint



HWY-132
PLANT ENTRANCE ROAD
MAIN GATE
CONTRACTORS STORAGE
FENCE 10' HIGH
PSV STORAGE & STAGING
ENCLOSED SHED OR AIR SUPPORTED STRUCTURE FOR STORAGE 300' X 60'
WELLPAD D
PUU HONUAULA
SWITCH YARD
WELDING ASSEMBLY SHED
WELLPAD C
POWER PLANT
WELLPAD B
ROAD
ROCK MUFFLERS
WELLPAD A
HOLDING POND
WELLPAD E
POHOIKI ROAD
ROAD
WELLPAD F
HGP-A (EXIST)
OVERALL SITE PLAN
SCALE: FEET
GRAPHIC SCALE
KAUAI
OAHU
MOLOKAI
MAUI
HAWAII
HAWAIIAN ISLANDS
SCALE: NONE
HILO
PAHOA
PROJECT LOCATION
TRUE
MAGNETIC
HWY 132
POWER PLANT
LEILANI AVE.
POHOIKI ROAD
SCALE: MILES
SCALE: FEET
GRAPHIC SCALE
VICINITY MAP
ITEM OR FIND NO.
QTY REQ
PART NO
DESCRIPTION
PARTS LIST
ORMAT SYSTEMS
OVERALL SITE PLAN

Figure 3-16

Table 3-15. SAAQS and NAAQS Evaluation for H_2S and Particulates

Total Pollutant	Averaging Period	2nd Highest Monitored Concentration[1] ($\mu g/m^3$)	2nd Highest Modeled Concentration[2] ($\mu g/m^3$)	Maximum Concentration ($\mu g/m^3$)	SAAQS ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)
H_2S (proposed)	1-hour	19.0	99.0	118.0	139	
PM (TSP)	24-hour	39.0	22.0	61.0	150	-
	Annual Arithmetic Average	20.0	<1	<21	60	-
PM (PM_{10})	24-hour	16.9	12	28.9	-	150
	Annual Arithmetic Average	7.5	<0.3	<7.8	-	50

Notes:

[1]The second highest monitored H_2S concentration based on data presented in Table 3-14. The second highest 24-hour and annual average monitored PM_{10} concentrations are based on data recorded at the Hawaii Volcanoes National Park visitor center and the Bishop Estate Leasehold during the period December 1982 through March 1983. The PM_{10} annual average concentration is based on the average of 29 samples taken March-August 1988. The 24-hour average TSP concentration is the highest monitored value and the annual average TSP concentration is based on the average of 14 biweekly samples taken during that period.

[2]The second highest modeled 1-hour H_2S concentration is based on Case 4 presented in Table 3-13. The second highest particulate concentrations are based on Case 3; the annual average PM_{10} concentrations are based on Cases 2 and 4; annual TSP concentrations are from Case 1.

schemes will be used to blend in structures with the surrounding environment.

Removal of all the temporary structures from the construction yard site, the fence surrounding the site and surplus materials will take place after construction is completed and the full project has commenced commercial operation. Growth of natural plants will then be encouraged.

3.2.5.Operation and Maintenance

The operational life of the PGV Project facilities is estimated to be 35 years. The power plant and wellfield will be operated in a manner that protects human health and the environment. The facility staff will operate equipment, oversee production, and respond to emergencies. An important part of the operational phase of the project is regular maintenance and monitoring of both the power plant and the wellfield. Monitoring is discussed in Section 3.12 of this document.

Approximately 19 employees will be required for ongoing operation and maintenance of the facility. Most of the employees will be local residents.

The power plant and wellfield will operate continuously 24 hours per day, seven days per week. Qualified operators will be onsite at all times when the plant is operating. Routine maintenance will be conducted by workers during the normal daytime work shift. If repair work is required because of reduced power generation because of malfunction of part of the power plant, the maintenance work will continue 24 hours per day, seven days per week, until full power output can be resumed.

Wellfield maintenance will generally be performed without shutting off the flow of steam from any well. When this action cannot be taken or is unsafe, maintenance work for the wellfield will be phased so that the fewest possible number of wells will be closed down (shut in), and those wells will be shut in for a minimum time. Remedial drilling of a well, called well workover, is typically needed for proper wellfield maintenance. Well workovers are anticipated every 2 to 5 years for each well.

Scheduled power plant maintenance will be conducted for each steam turbine generating unit at intervals of one to two years, as needed. Thorough maintenance procedures, such as turbine disassembly and inspection, will be conducted during these planned outages. Because the plant output will be reduced during this scheduled maintenance, they will be coordinated with HELCO to ensure the maintenance of a reliable power system. Appropriately sized maintenance crews will be engaged around the clock, seven days per week, during this time. Work crews will work 8- to 12-hour shifts.

3.2.6.Plant Start-Up and Shutdown

The modular nature of the power plant allows a gradual start-up process as relatively small increments of power are synchronized to the grid, one at a time. The total process is relatively rapid due to the small moment of inertia and small volume to be heated during each step of the start-up process.
As start-up after a complete plant shut down begins, wellfield production will be 50 percent of the full steam flow, which will be released through the rock muffler. The power generation modules will enter production gradually, following the sequence

outlined below, and the flow to the rock mufflers will be reduced gradually until the power generating units are able to receive the 50 percent steam production.

The start-up of the generating modules typically begins with energizing the auxiliary systems needed for starting one OEC unit. These auxiliary systems include the air compressor, OEC lube and sealing oil pumps, condenser fans for one OEC unit, and working fluid circulation pump. The power for the auxiliary systems can be supplied either from the 250 kW diesel generator or from the utility grid.

To start an OEC unit, the steam turbine bypass will be opened, and the steam gradually let into the OEC vaporizer until it reaches full flow. After the start-up and synchronization of the first OEC unit, the power plant will supply its own power and also supply power to the grid. As more OEC units are started and synchronized, the wells will be opened up to allow more steam to flow from the wellfield.

The steam turbine paired with each OEC unit can be started as soon as its OEC unit is in operation. The steam will be gradually introduced into the steam turbines and increased until full-load steam turbine operation is achieved.

Shutdown of each OEC/steam turbine module will be handled in reverse order, i.e. first the steam flow to the steam turbine is gradually reduced while the steam turbine bypass is gradually opened. After the steam turbine is shut down, the steam to the OEC unit is gradually closed. When a complete shutdown plant is planned, the steam valve to the emergency steam release rock muffler will be opened gradually as the steam flow is reduced to about 50 percent of the design flow. Finally, either the diesel generator or the utility grid will be supplying the power to the auxiliaries after the last OEC unit has been shutdown.

Shutting down wells and returning them to service is generally minimized in geothermal operations around the world because it can cause damage to the wells and/or reduce their expected life.

3.2.7.Decommissioning

Decommissioning refers to the proper abandonment of the wellfield and removal of structures and equipment at the end of the useful life of the project. Economic and resource conditions will dictate when the facility should be decommissioned. The following steps will be taken during decommissioning:

- Structures and piping will be removed.
- Wells will be plugged with cement in accordance with procedures contained in the DLNR well drilling permits and regulations.
- Wellhead equipment and casing will be removed to below grade and the well casing capped.
- Roadways will be abandoned to the extent agreed upon with the landowner.
- The site will be regraded to approximate original contours, and the project area will be seeded or planted with natural vegetation, as appropriate.

3.3. Plot and Site Plans

This subsection provides "a preliminary plot or site plan of the property, drawn to scale, showing all existing and proposed uses and locations of structures including, but not limited to, drilling sites, wells, access roadways, water sources, waste water collection and disposal systems, the geothermal steam and/or brine collection and disposal systems, power plant(s) and electrical power distribution systems," as required by Rule 12.3(b)(2) part (C).

Preliminary site plans for the PGV Project area are presented in Figure 2-2 and Figure 3-4. The layout of a typical geothermal wellpad during drilling operations is presented in Figure 3-7, and that of a typical wellpad after completion of drilling, during normal operation, is shown in Figure 3-5. A plot plan showing the general arrangement of the PGV Project power plant site is presented in Figure 3-13. During construction of the power plant and wellfield, temporary working areas will be used for storage and fabrication of materials and equipment and for the construction administration offices, as shown in Figure 3-16. As described in Section 3.2, these plans depict existing and proposed uses and locations of structures including access roads, wellpads, collection and disposal systems, power plant, and electrical power distribution systems. Potable water will be supplied by the county system or a rain-catchment system. The intertie between the power plant and the electrical switchyard is also shown on the site plans.

As described in Section 3.2.1.1, all wells will be drilled from one of the six proposed wellpads, on an as-needed basis. The specific drilling target and wellpad location for each well will be identified in the drilling permit applications which are required by the Department of Land and Natural Resources (DLNR).

3.3.1. Visibility Criteria Used in Siting the Facilities

Visual concerns were an important criteria in choosing the location of the power plant and wellpads. The layout of the facility is designed to minimize the amount of land required for clearing. Cut-and-fill slopes will be engineered to minimize the visual impacts created by clearing and grading activities, so that the transition to the surrounding terrain appears more natural.

As discussed in Section 3.4, all proposed power plant facilities will be low-profile structures. None of the proposed structures will exceed 24 feet in height, with the exception of the ten 14-inch diameter isopentane emergency vent stacks which rise approximately eight feet above the air coolers. Similarly, all project lighting will be shielded from the direction of potential offsite visual receptors.

3.3.2. Site Landscaping

Landscaping will be installed around the power plant and wellpads to screen the industrial structures and equipment from view. The choice of vegetation will take into account the species' height and camouflaging ability. For compatibility, native plants will be used to the extent feasible. Almost all of the undeveloped lots in the surrounding subdivisions are densely forested and a vegetation screen can be left when they are developed.

Facility structures, including pipelines, will either be painted to blend into the surrounding environment or constructed of such material that their surface textures will blend in with surrounding vegetation. Dark green or dark gray colors will be used, depending on background vegetation and rocks. Reflective metal surfaces will be coated or screened with solid fencing.

Once planted landscaping matures, the vegetation will effectively screen the proposed plant structures.

3.4. Elevation of Structures

This subsection provides "preliminary elevation drawings of the proposed temporary and permanent structures," as required by Rule 12.3(b)(2) part (D).

Figure 3-7 is a view of a typical geothermal drilling rig during drilling operations, which shows the rig floor, derrick, drawworks, trailers and other equipment necessary for the drilling of each well. As stated in Section 3.2.1.3, each well will require, on average, approximately 45 days to drill, after which the drill rig will be moved to the next well, either on the same or another wellpad. During approximately the first two years after the start of construction, the drill rig will be in almost constant use. Once all the wells required for initial operation of the full 25 MW project are drilled, the drill rig will be utilized only for drilling makeup wells and well workovers, and when not in use will either be removed from the project area or stored onsite with the derrick retracted.

Figure 3-15 provides preliminary elevation drawings of the principal PGV Project power plant facility structures. The locations of the structures were identified in the site plan (Figure 2-2) and the power plant general arrangement (Figure 3-13). Preliminary dimensions and elevations of the main structures shown in the preliminary elevation drawing are also listed in Table 3-6. Detailed elevation drawings will be developed during the final engineering and design phase of the PGV Project. Figure 3-17 gives preliminary elevation drawings of the temporary structures which will erected during construction, as shown in Figure 3-16.

Table 3-6. Preliminary Dimensions of Principal Project Structures

Structure	Length (feet)	Width (feet)	Height[1] (feet)
Turbine Building (w/ switch gear)	130	30	24
Air Coolers	5 x 56	60	24
Control and Maintenance Building	170	40	20
Transformer	10	8	15
Standby Generator/Shed	25	20	15
Moisture Separators	6 dia		20
Brine Flash Separator	6 dia		12
Condensate Drum (horizontal)	10	6 dia	6
Water Tank	50 dia		24
NaOH Tank (10%)	25 dia		22
NaOH Tank (50%)(horizontal)	25	10 dia	10
Rock Mufflers	14 dia		14
Fence			6
Isopentane Tank (2 units)	30	7 dia	11
Isopentane Vent Stack (10 units)		14 inch	32
OEC Electrical Room (10 units)	20	12	10
OEC Unit (each)	40	8	12
OEC Vaporizer	46	4.5 dia	6
Wellpads	300	400	1
Wellheads	10	10	0
Switchyard	150	150	10

[1]Elevations above grade

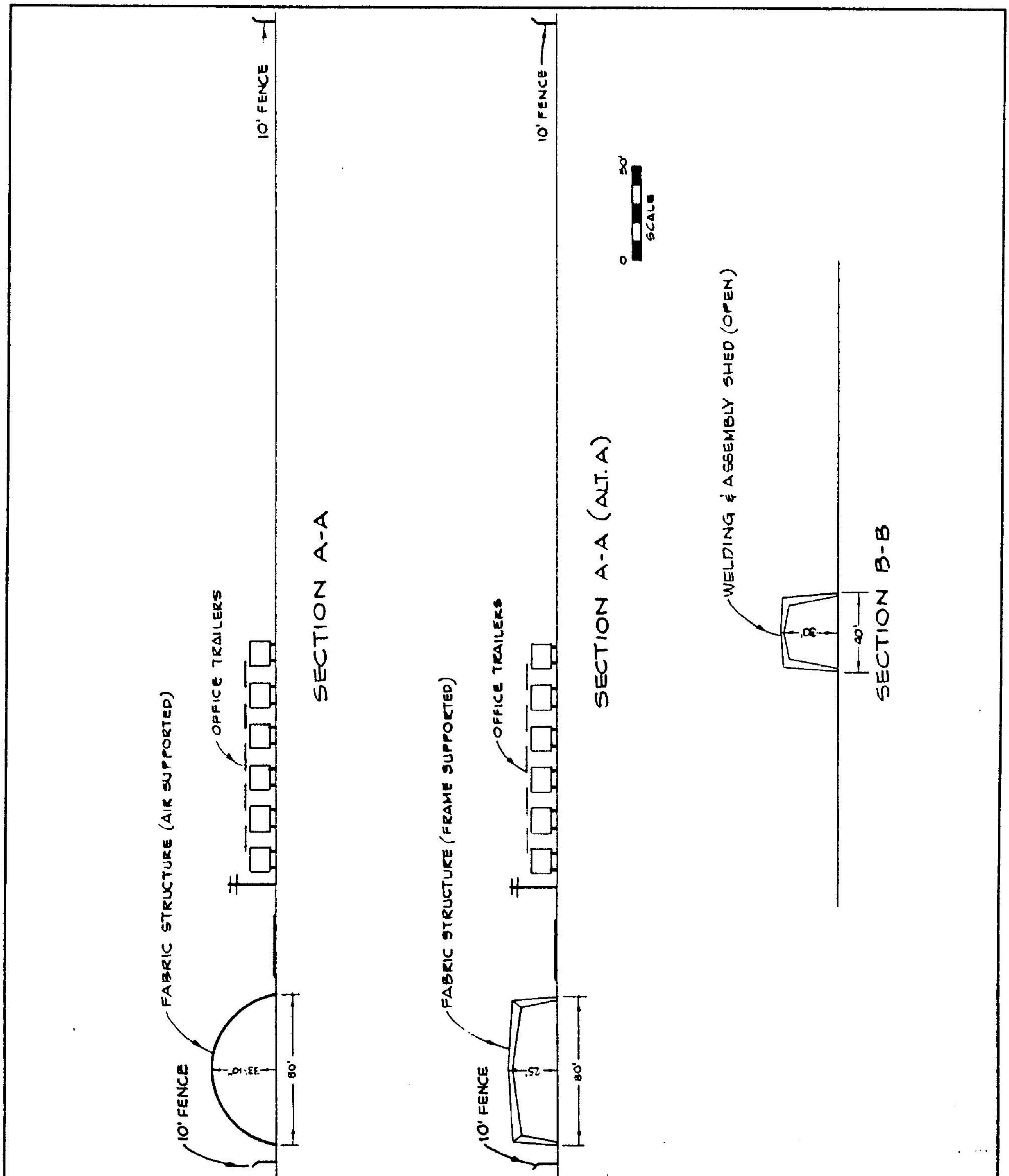


Figure 3-17. Preliminary Elevation Drawings of the Temporary Structures

An artist's rendering of the proposed PGV Project power plant and the immediately adjacent wellpad, which will show approximately how these facilities will appear once constructed, is currently under development. By utilizing smaller steam turbines, OEC units, and air coolers instead of cooling towers, the revised PGV Project will have a substantially lower profile (approximately 24 feet) than the previously proposed PGV Project (approximately 36 feet), and will not produce any water vapor plumes which would rise above the plant. To assist in the visualization of how the power plant will look, Appendix C provides photographs of other geothermal power plants which utilize OEC units as the principal generation units, some of which are also air cooled. Although the PGV Project power plant, like most other power plants, will have a unique design to accommodate the specifics of its location, geothermal resource, etc., the photographs of the power plants shown in Appendix C can be used to help envision what the PGV Project power plant will look like.

3.5. Wellhead Structures and Wellcasing Program

Rule 12.3(b)(2) part (E) requires a discussion of "the proposed locations and elevations and depths of all superstructures and drilling rigs, bottom hole locations, casing program, proposed well completion program, size and shape of drilling sites, and location of all existing and proposed access roads."

The proposed locations of the wellpads, the wellpad superstructures, the well completion program, the casing program,and the location of the access roads are all presented in Section 3.2.1. A detailed description of the proposed drilling and casing program is presented in Appendix B.

3.6. Surface Disturbance

This subsection discusses "areas of potential temporary and/or permanent surface disturbance, including, but not limited to, excavation and grading sites, the location of camp sites, airstrips, and other support facilities, excavation and borrow pits for roads and other construction activities," as required by Rule 12.3(b)(2) part (F).

About 6 percent of the 500-acre project area will be disturbed by the PGV Project. Approximately 24.5 surface acres will be required for the power plant, six wellpads, access roads, piping routes, switch yard, and brine pond. Another 5 acres will be used as a temporary construction yard. Nine of the acres have been cleared, and two more acres do not need clearing because they are covered with barren lava flow.

Most of the project area is relatively level, recently cultivated land or lava flows, and little grading will be required. Two wellpads, approximately four acres total, have already been graded, leaving 20.5 acres to be graded. The areas that will be disturbed are immediately around the power plant structures, the wellpads, along the piping routes, within the temporary construction yard, within the switchyard, and along the new access road off of Highway 132. The graded areas will be comparable in size to those created when homes are constructed in nearby subdivisions and far smaller than those associated with existing agricultural activities. A grading plan for each area will be submitted to the county prior to construction.

All construction materials and equipment will be kept within the graded areas or on internal roads within the project's boundaries. Adequate space is available onsite to use as a staging area for the construction. No offsite construction yards or bases are anticipated.

3.7.Disposal of Well Effluent and Other Wastes

This subsection provides "a written description of the methods for disposing of well effluent and other wastes," as required by Rule 12.3(b)(2) part (G).

Produced geothermal brines, steam condensate, and noncondensable gases will be disposed of through injection into the geothermal reservoir. Injection is essentially a closed loop disposal system since all geothermal fluids are returned to the geothermal reservoir. The injection system is discussed in further detail in Section 3.2.1.7, and the noncondensable gas control system, which feeds into the injection system, is discussed in Section 3.2.2.2.

The proposed project will also generate less than 200 gallons of domestic wastewater per day. Sewage disposal in the Puna District is by means of individual cesspools and septic systems. Current plans are to dispose of domestic wastewater onsite in cesspools. These cesspools are expected to perform satisfactorily due to the highly porous nature of the soils and underlying rock. Portable toilets may also be used during peak construction periods. No public drinking water sources would be affected by the proposed system.

3.8.Geologic Report

This subsection discusses "a geologist's report on the site and surrounding area's surface and subsurface geology, nature and occurrence of known or potential geological hazards and geothermal resources, surface and groundwater resources, topographic features of the land, and drainage patterns" as requested in Rule 12.3(b)(2) part (H).

As stated above in Section 3.2.1.1., the PGV Project area is located in a geologic region known as the Lower East Rift Zone (LERZ), found on the eastern flank of Kilauea Volcano. Kilauea is one of the world's most active volcanoes, and the LERZ is a conduit for lateral migration of basaltic magma flowing east-northeast from the caldera at the summit. The magma in this subsurface conduit provides the heat source for the high-temperature Puna geothermal reservoir, which in turn affects the groundwater resources in the area. The volcanic nature of the region requires consideration of the risks associated with volcanic eruptions, lava flows, and faulting.
Beneath the surface features of the LERZ, at depths below 8,000 feet, is thought to be a 5- to 15-mile wide dike complex, where temperatures approach 1,900°F, the melting point of basalt. A secondary magma chamber is thought to be located within the LERZ beneath the geothermal reservoir. The series of dikes convey heat to the high-temperature geothermal reservoir, a system of vertical to near-vertical fractures which contains a two-phase geothermal resource with temperatures as high as 600°F below 4,000 feet. Overlying the high-temperature geothermal reservoir is a relatively impermeable layer of capping rock, generally at depths of between 4,000 and 2,500 feet below the surface, although both the upper and lower boundaries of the

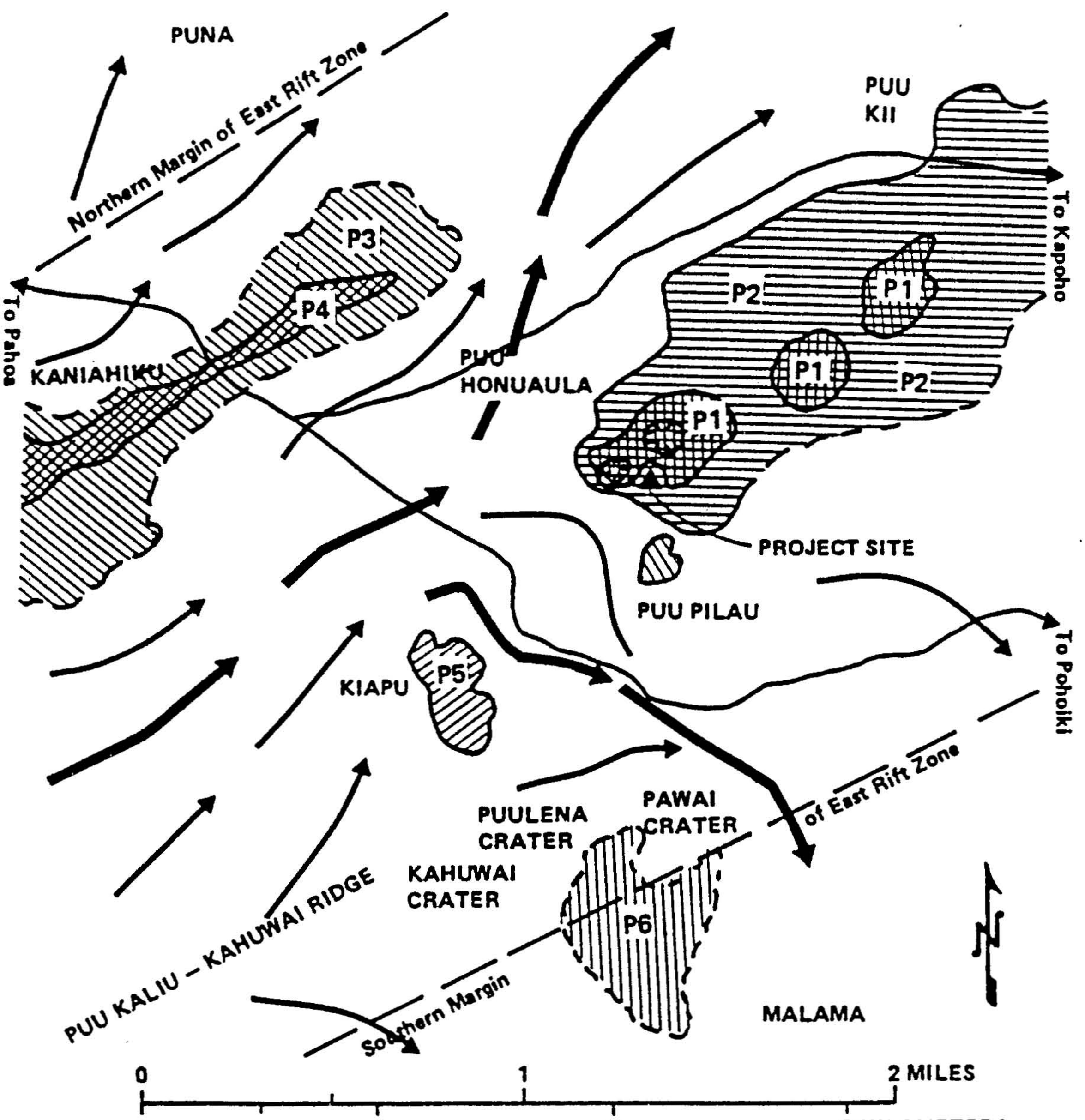
caprock are variable and dependent upon the local permeability (fractures). Figure 3-2 depicts a conceptual model of this Puna geothermal reservoir.

A zone of vigorous groundwater flow extends from the top of the generally impermeable caprock to the water table, approximately 600 feet below the surface. The groundwater in this upper aquifer is thermally and chemically influenced by natural leakage of geothermal fluids through the caprock from the geothermal reservoir below. The groundwater regime is charged by rainwater; as much as 120 inches a year fall at the site and percolate downward through the porous volcanic soil and rock. The dikes and faults of the LERZ affect the flow of this groundwater; natural leakage of geothermal fluids from the geothermal reservoir affects its quality. Sampled groundwaters in the site area, near where the fault traverses the LERZ, have temperatures ranging from 100 to 199°F, chloride-to-magnesium (Cl/Mg) ratios of 18 to 2000, silica content of 24 to 105 ppm, and total dissolved solids (TDS) concentrations of 762 to 11,700 ppm. This chemical signature led Ivonetti to classify the groundwater waters in this region as "geothermal." Upwelling "geothermal" waters form two plumes, one flowing parallel to the rift to form a mixed groundwater region at Kapoho Crater, the other forming a broad plume that follows topography, discharging as warm springs and seeps along the Puna coast.

The proposed project must be designed for volcanic and seismic hazards. Since the area has been subject to lava flows as recently as 1955, 1960, and 1961, the risks of renewed flows was considered in siting the proposed facilities. The power plant site is on relatively high ground (elevation 670 feet), approximately 40 feet above the surrounding terrain at the southern base of Puu Honuaula and the adjacent puu, which places it at a relatively low risk of inundation from uprift lava flows (see Figure 3-18). Wellpads B, C, and D are at higher elevations (680 to 720 feet), and thus lower risk, while the wellpads to the southwest, Wellpads A, E, and F, are at elevations of 620 to 640 feet, which place them at higher risk. All the geothermal wellheads will be placed in cellars that can be readily filled with volcanic cinders to reduce the chances of structural failure in the event of a lava flow. The other facilities will be designed to be isolated as much as possible and/or removed or abandoned in the event they are seriously threatened by a flow capable of inundation. Close coordination with the U.S. Geologic Survey and the Hawaii Institute of Geophysics will ensure as early a warning of anticipated volcanic activity as possible.

Volcanic and tectonic activity also poses risks of fissuring, ground acceleration, surface deformation, and subsidence. The maximum anticipated ground acceleration is 0.4 g, and the proposed facilities will be designed for movements in excess of this, in conformance with Seismic Zone 4 requirements. The steam and brine pipelines will be designed with expansion loops to accommodate thermal stress, which may also minimize the effects of fissuring, subsidence, and ground swelling which could occur in the project area.

The withdrawal of geothermal fluids is not likely to induce subsidence because the geothermal reservoir consists of dense, structurally competent basalts which resist compaction. In addition, because all geothermal fluids will be injected back into the geothermal reservoir, there will be no significant reductions of reservoir pressure. The injection of fluids into the geothermal reservoir may have the possibility of increasing



Map showing relative risk of lava flow incursions. Arrows show likely directions of flow of lavas in future eruptions. The most likely paths of flow are shown with thick arrows. P1 marks areas with lease risk of lava incursion and P6 marks areas of intermediate risk. Unshaded areas are those of greatest risk. (After Slemmons, 1981)

Figure 3-18. Puu Honuaula Area Volcanic Risk Levels microseismic activity, but the possible levels of induced activity are significantly less than currently experienced in the area, which is one of the most seismically active regions in the world.

3.9. Background Meteorology, Air Quality and Noise Levels

This subsection presents "pre-exploration meteorological ambient air quality and noise level measurements that demonstrate the potential effects on surrounding properties through air quality and noise analysis," as required by Rule 12.3(a)(2) part (I).

Preconstruction site meteorology, ambient air quality, and noise level measurements have previously been taken in the project area to provide the basis for air quality and noise level impact analysis. PGV has conducted meteorology and air quality monitoring studies in the Puna region since 1981. An environmental noise survey was conducted at the PGV site during early September 1986.

The assessment of the effects of the emissions of H_2S and particulates from the proposed PGV Project wellfield and the proposed PGV Project power plant on the local ambient air quality involves a comparison of the estimated impacts with the proposed Hawaii State Ambient Air Quality Standard (SAAQS) for H_2S, the existing SAAQS for total suspended particulates (TSP), and the National Ambient Air Quality Standard (NAAQS) for particulates less than 10 microns in diameter (PM_{10}).

3.9.1.Meteorology

PGV has conducted comprehensive meteorology monitoring studies of the "Woods" site (1.1 miles northwest of the power plant site) since April 1982 (see Figure 3-19). PGV also analyzed annual wind speed distribution data at the "Woods" site for the period October 1982 through September 1983 and these data were used in the air dispersion modeling. These data show that the prevailing wind flow is from the west during the nighttime and from the north to northeast during the daytime. The nighttime westerly winds shown derive from downslope flows due to thermal gradients on adjacent terrain while the north-to-northeast daytime winds derive from the trade wind flow.

3.9.2.Air Quality

3.9.2.1.Background Air Quality

An H_2S air quality data base is available to establish the background air quality for the area surrounding the project. The ambient monitoring stations are shown in Figure 3-19 and are described below:

- The "Schroeder" site is located approximately 1.3 miles (2 km) south-southwest of the HGP-A well site. H_2S ambient monitoring began in March 1981. This was the first H_2S monitoring site to be established;

- The "Hess" site is located approximately 1.3 miles (2 km) southwest of the HGP-A well site. This station began H_2S monitoring in July 1982, and was discontinued in January 1984;

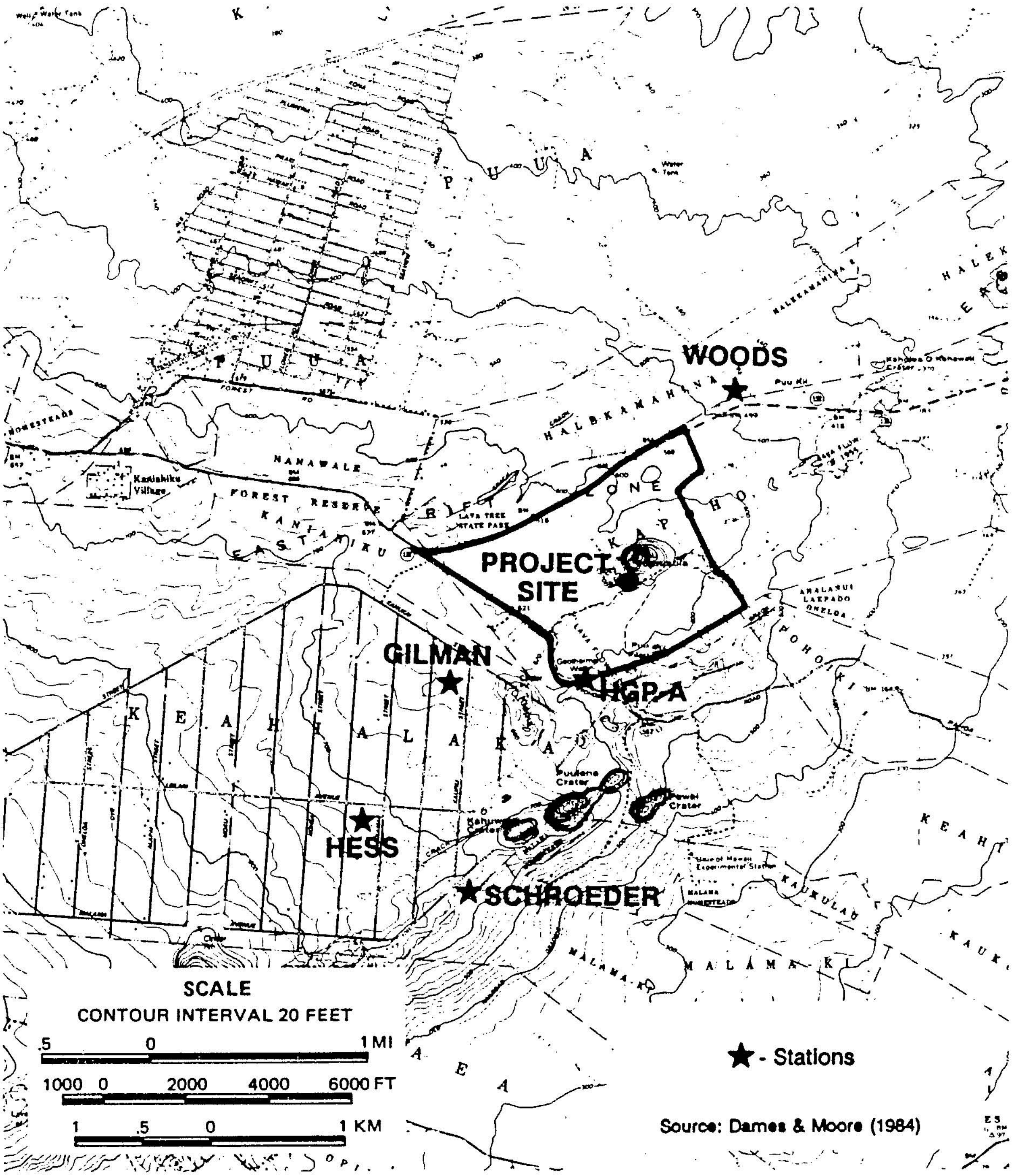


Figure 3-19. Air Quality Monitoring Stations

- The "Gilman" site is located approximately 0.6 miles (1 km) west of the HGP-A well site. Monitoring began in 1981 with comprehensive data retrieval in April 1982; and

- The "Woods" site is located approximately 1.1 miles (1.7 km) north of the HGP-A well site. Monitoring began in 1981 with comprehensive data retrieval in April 1982.

NEA, Inc. and Alpha Micro Systems, Inc. have recorded ambient H_2S concentrations for the Hawaii Department of Planning and Economic Development (Dames & Moore, 1984). Data collected and reported through 1983 for the "Schroeder", "Gilman", and "Hess" sites and through June 1987 for the "Woods" site are shown in Table 3-7.

These data indicate that H_2S ambient levels are below 14 $\mu g/m^3$ (0.010 ppmv) from all stations over the past six years about 98 percent of the time. The highest H_2S levels were 67.2 $\mu g/m^3$ (0.048 ppmv) at the "Schroeder" site in the early 1980s. This site is located southwest of the HGP-A well site.

Data for 1988 from three stations, "Gilman," "Schroeder," and "Woods," are also included in Table 3-7. These data show the current ambient air quality and reflect the present level of abatement on the 3 MW HGP-A project. The average concentration of all three air quality stations in 1988 was 3.5 $\mu g/m^3$ (0.003 ppmv), which is at or below the detection limit of the monitoring equipment. In 1988, only two hours exceeded 14 $\mu g/m^3$ (0.010 ppmv), one of which represents a reading during a period of HGP-A H_2S equipment malfunction. Higher levels were recorded at the "Fenceline" station at the HGP-A boundary. The 1988 "Fenceline" data showed an average concentration of 11 $\mu g/m^3$

Table 3-7. Summary of H_2S Air Quality Monitoring Data

Time	"Woods"[1] Highest ($\mu g/m^3$)	"Woods"[1] 2nd Highest ($\mu g/m^3$)	"Gilman"[1] Highest ($\mu g/m^3$)	"Gilman"[1] 2nd Highest ($\mu g/m^3$)	"Schroeder"[1] Highest ($\mu g/m^3$)	"Schroeder"[1] 2nd Highest ($\mu g/m^3$)	"Hess"[1] Highest ($\mu g/m^3$)	"Hess"[1] 2nd Highest ($\mu g/m^3$)
March 1981-June 1987	22	21	29	22	67	29	19	7
January 1988 - December 1988	19	7	22	10	9	9	N/A	N/A

[1]Locations of the air quality monitoring sites are presented in Figure 3-19.

(0.008 ppmv), with the two highest hourly readings being 25 $\mu g/m^3$ (0.018 ppmv) and 24 $\mu g/m^3$ (0.017 ppmv). These H_2S ambient levels can be compared with the proposed ambient 1-hour standard of 139 $\mu g/m^3$ (0.1 ppmv).

TSP has been monitored using high volume samplers at two locations in Puna. The first location is the Bishop Estate Leasehold, about 3 miles southwest of the power-plant site; the second is the visitor center of the Hawaii Volcanoes National Park about 13.2 miles northwest of the power plant site. Data from the Bishop Estate Leasehold showed that the 14 biweekly samples between December 1982 and March 1983 averaged a 24-hour TSP level at 20 $\mu g/m^3$. The highest value at the visitor center was 39 $\mu g/m^3$. These TSP values can be compared to the 24-hour average SAAQS of 150 $\mu g/m^3$

PM_{10} has been monitored at the Hawaii Volcanoes National Park since March 1988. Data from 29 samples collected between March 1988 and August 1988 showed a 24-hour average PM_{10} concentration of 7.5 $\mu g/m^3$, with the two highest values 27.1 $\mu g/m^3$ and 16.9 $\mu g/m^3$. These values can be compared to the federal 24-hour PM_{10} NAAQS of 150 $\mu g/m^3$.

3.9.2.2.Air Quality Impact Analysis

The air quality impact analysis considers wellfield sources, power plant sources, and combined sources. Impacts of H_2S and particulate emissions from the Puna geothermal plant were assessed using the EPA dispersion model COMPLEX I. Individual wellfield sources were modeled as point sources.

For the wellfield, sources were modeled for Wellpads E and F, as these pads are closest to the property boundary and to the local residences along the Pahoa-Pohoiki Road. For combined source cases, power plant sources were combined with Wellpad E sources because, of the two wellpads, Wellpad E is closer to the property boundary.

Two sets of receptors were used for the COMPLEX I modeling; a set of polar coordinates, internally generated receptors, and a set of discrete receptors. These are the same receptors used for the previous modeling analysis. Receptors were located at 36 points on each of the 7 rings about the power plant site. Receptor rings were located at distances of 0.7 to 4.5 km from the center of the power plant site. An additional 141 receptors were located in a rectangular coordinate grid south-southwest and west-northwest of the power plant site. This grid included 21 receptors along the property boundary. Only impacts at receptors on or outside of the property boundary are considered in the impact assessment.

3.9.2.2.1.Emission Rates

Table 3-8 and Table 3-9 list the annual emission rates for each of the potential pollutants from the PGV wellfield and the PGV power plant respectively, for which there is an NAAQS or SAAQS or which the DOH Air Pollution Control Administrative Rules have adopted a significance level.

Table 3-9 also includes the total annual emissions for the PGV wellfield during field development and after the wells are connected to the power plant. The wellfield emissions after connection to the power plant are based on drilling and testing of three wells a year, the maximum level of activity that is expected to occur concurrently with power plant operations. Table 3-9 also includes isopentane (C_5H_{12}) emissions, even though it is not a criteria pollutant and no significance level has been established for it.

Table 3-10 compares the total annual emissions of pollutants from the wellfield and the power plant with the significance levels established by Section 11-60-1 of the DOH Air Pollution Control rules. As Table 3-10 indicates, the proposed PGV wellfield and the proposed PGV power plant will not emit significant amounts of any pollutant regulated by the Clean Air Act.

Table 3-8. Potential Emissions From Wellfield Sources

	Well Drilling	Well Venting	Well Testing	Pipeline Cleanout	Fugitive Emission	Power Plant	Total
				(tons/year)[1]			
Prior to Connection to Power Plant[2]							
H_2S	0.17	1.87	4.25	0.20	N/A	N/A	6.49
TSP	0.17	3.20	1.01	0.003	N/A	N/A	4.38
Hg[3]	0.00001	0.00007	0.003	0.00008	N/A	N/A	0.0034
NOx[4]	35.4	N/A	N/A	N/A	N/A	N/A	35.4
CO[4]	7.4	N/A	N/A	N/A	N/A	N/A	7.4
SOx[4]	5.4	N/A	N/A	N/A	N/A	N/A	5.4
After Connection to Power Plant[5]							
H_2S	0.06	0.70	2.12	N/A	0.31	0.22	3.41
TSP	0.06	1.20	0.50	N/A	0.00	0.07	1.83
Hg[3]	0.000003	0.00002	0.002	N/A	N/A	0.00008	0.002
NOx[4]	13.3	N/A	N/A	N/A	N/A	N/A	13.3
CO[4]	2.8	N/A	N/A	N/A	N/A	N/A	2.8
SOx[4]	2.0	N/A	N/A	N/A	N/A	N/A	2.0

[1] Emissions data is based upon composite Puna geothermal reservoir fluid samples and the source operation and emissions data presented in Section 4.

[2] Assumes 8 wells drilled (6 production, 2 injection) with 6 wells vented and tested at 90,000 lb/hr steam for 240 hours.

[3] Assumes all mercury in the brine is emitted with the steam, an extremely conservative assumption.

[4] Three 440 kW diesel generators operation at an average load factor of 0.3 during drilling. One 440 kW diesel generator on standby.

[5] Assumes 3 wells drilled or reworked and tested at 90,000 lb/hr steam for 240 hours.

Table 3-9. Potential Emissions from Power Plant Sources

Pollutant[1]	Piping Manifold	Rock Muffler	Diesel Generator[2]	Isopentane Release[3]	Total
	tons/year				
H_2S	0.09	0.59	N/A	N/A	0.68
TSP	0.001	0.17	0.03	N/A	0.20
Hg	N/A	0.0012	N/A	N/A	0.0012
CO	N/A	N/A	0.08	N/A	0.08
NO_x	N/A	N/A	0.33	N/A	0.33
SO_2	N/A	N/A	0.03	N/A	0.03
C_5H_{12}	1.75	N/A	N/A	2.5	4.25

[1]Emissions data based upon composite Puna geothermal reservoir fluid samples and the source operations and emissions data presented in Section 4.

[2]Based on 50 hours of operation of the 250 kW generator per year, 20 hours operation of the 315 hp firewater pump.

[3]Based on two emergency releases of 2,500 lb isopentane a year.

The PGV wellfield, nevertheless, will employ BACT to the wellfield sources of emissions in order to maintain the proposed low rates of emissions and to meet the Department of Health rules. The 25 MW power plant will achieve low emission rates by eliminating the cooling towers which were a major source of emissions, and by injecting all but fugitive geothermal fluids and gases back into the reservoir.

Table 3-10. Comparison of Project Emissions with Significance Levels

Pollutant	Power Plant[1] Emissions	Wellfield[1] Emissions	Significant[2] Emission Rate
		(tons/year)	
H_2S	0.68	6.49	10.0
TSP	0.20	4.38	25.0
Hg	0.0012	0.003	0.1
CO	0.08	16.18	100.0
NOx	0.33	101.8	40.0
SO_2	0.03	9.0	40.0

[1]Emissions data is based upon composite Puna geothermal reservoir fluid samples and the source operation and emissions data presented in Attachment P-10 in Section 2.

[2]Significance levels based definition of significant on Section 11-60-1 of Chapter 60.

3.9.2.2.2. Impacts of Wellfield Sources

The maximum predicted impacts from well drilling, well venting, well flow testing, pipeline cleanout and fugitive emissions for H_2S and particulates at the receptor locations on and outside of the project boundary are given in Table 3-11. The maximum model impact (i.e., most conservative) for all sources modeled is based on modeling with the October 1982 through September 1983 meteorological data base.

The maximum 1-hour H_2S project impact modeled was caused by well cleanout venting. Since these impacts are not acceptable, PGV

Table 3-11. Maximum H_2S Concentrations from Wellfield Operations

		Wellpad E			Wellpad F		
Wellfield Source	Rank	1-Hour Average H_2S Concentration ($\mu g/m^3$)	Location with respect to Wellpad E: Azimuth (deg)	Location with respect to Wellpad E: Distance (km)	1-Hour Average H_2S Concentration ($\mu g/m^3$)	Location with respect to Wellpad F: Azimuth (deg)	Location with respect to Wellpad F: Distance (km)
Well Drilling	1	48	202	0.2	41	233	0.3
	2	46	162	0.3	35	220	1.5
Well Venting[1]	1	77.3	266	0.5	69.8	253	0.8
	2	75.3	208	0.8	69.7	204	0.7
Well Flow Testing	1	22	162	0.2	20	233	0.3
	2	19	226	0.3	13	228	2.6
Pipeline Cleanout[12]	1	81.6	312	0.7	81.6	312	0.7
	2	79.9	302	0.7	79.9	302	0.7
Fugitive Emissions	1	4	162	0.2	6	94	0.1
	2	3	226	0.3	3	233	0.3

[1] Venting during daytime (neutral, unstable) periods with windspeeds ≥ 4 m/s (8.9 mph).

[2] Cleanout emissions from all pipelines will be emitted at the power plant site.

Source: Aerometric Monitoring, Inc.

reviewed the meteorological data to determine what conditions would provide adequate dispersion of vented H_2S emissions. The maximum impact of venting is 77 $\mu g/m^3$ H_2S which occurs when vertical cleanout venting takes place at daylight neutral or unstable periods in which windspeed is greater than 4 m/s (8.9 mph). Based upon this analysis, PGV plans to schedule well venting only during those periods when winds equal or exceed 4 m/s and are expected to continue to do so. The same criteria will be applied to pipeline cleanout emissions.

The COMPLEX I model was also run to estimate impacts from well cleanout venting at the H_2S monitoring stations ("Gilman", "Woods", "Hess", Schroeder"). With the meteorological restriction of daytime, windspeed ≥4 m/s, the highest 1-hour H_2S concentration at any of the monitoring sites was 63.9 $\mu g/m^3$ at the "Gilman" site.

The 24-hour average maximum PM_{10} and TSP concentrations from Wellpad E sources were 11.0 $\mu g/m^3$ and 22.0 $\mu g/m^3$ respectively for well venting. Table 3-11 lists maximum estimated concentrations from the wellpads closest to the property boundary and to scattered residences along Pahoa-Pohoiki Road. The impacts from other wellpads will be less at the property boundary because they are further away.

3.9.2.2.3. Impacts of Power Plant Sources

During normal operation, the PGV power plant emits only a negligible amount of H_2S. The maximum predicted impacts for H_2S from fugitive emissions and the emergency steam releases and their receptor locations are given in Table 3-12. The maximum model impact (i.e., most conservative) is based on modeling with

Table 3-12. Locations of Highest and Second Highest H_2S Concentrations from Power Plant Sources

		Maximum 1-Hour Average H_2S		
Power Plant Source	Rank	Concentration $\mu g/m^3$)	Azimuth (deg)	Distance (km)
Fugitive Emissions	1	0.1	195	0.7
	2	0.1	218	0.8
Emergency Steam Release	1	32.7	228	4
	2	25.3	225	2

the October 1982 through September 1983 meteorological data base.

The maximum 1-hour H_2S project impacts were 32.7 $\mu g/m^3$, caused by the first hour of emergency steam release and occurred at high terrain receptor locations about 4.4 miles southwest of the power plant site.

3.9.2.2.4.Combined Impact of Emission Sources

PGV will schedule its activities at the PGV Project to minimize the effects of simultaneous emissions of sources within the wellfield and at the power plant. The power plant will not be operating during the period of peak wellfield development. During the period of peak wellfield development, only one drilling rig is expected to be operating. However, the drilling of one well with aerated water or mud may overlap with the testing period of another well. Well venting, the activity which has the greatest impact on air quality, will be scheduled so that it does not coincide with the drilling with aerated water or mud or testing of another well or with pipeline cleanouts. Similarly, prior to start-up, the pipeline cleanouts will be scheduled so that they do not coincide with drilling with aerated water or mud, or well venting or flow testing of the wells.

When the power plant begins full operation, the only sources of emissions will be the fugitives from the wellfield and the power plant area. These emissions are conservatively estimated to be less than 0.1 lb/hr H_2S, and this situation is expected to occur more than 99 percent of the time. If an emergency steam release occurs, the power plant will cease operating, and the power plant fugitives will stop, but the wellfield fugitive emissions will continue.

Eventually, makeup well drilling and well workovers will occur in combination with power plant operations. Again, these wells will be drilled one at a time, with no more than three wells drilled during one year. Thus, well drilling (inadvertent releases during drilling with aerated mud or water) and testing emissions could coincide with power plant operations, as could well drilling with aerated mud or water and well venting emissions. The scenario with the greatest potential for combined emissions is one in which an emergency steam release occurs when a makeup well is being tested and another well is being drilled with aerated mud or water. The probability of this worst case scenario occurring is estimated at less than one in one million.

Four scenarios of combined emissions were modeled using the COMPLEX 1 model and the receptors discussed in Section 3.9.2.2. These scenarios are as follows:

Case 1: Normal Operations - Power Plant and Wellfield Fugitives

Case 2: Power Plant and Wellfield Fugitives, Well Drilling, Well Testing

Case 3: Power Plant and Wellfield Fugitives, Well Venting

Case 4: Emergency Steam Release, Wellfield Fugitives, Well Drilling, Well Testing

The results of the modeling for maximum 1-hour H_2S from the combined power plant and wellfield emissions, are presented in Table 3-13. Annual average concentrations are not shown for Case 3 because the total duration of this scenario is less than 24 hours a year.

3.9.2.2.5. Proposed SAAQS Increment Assessment

The proposed DOH geothermal power plant regulation requires that the maximum allowable increase in H_2S concentrations in ambient air above natural background levels consider all stationary sources (except geothermal wells during testing and routine maintenance) in the area affected by the proposed power plant. Table 3-14 compares the second highest modeled impact of the proposed PGV power plant (during normal operation) and the first hour of emergency steam release and the second highest monitored impact in the affected area, and compares this total to the proposed state allowable increment. The monitored H_2S levels overstate the HGP-A impacts as they also contain some background concentrations from scattered natural sources in the area. The high monitored levels also probably show the influence of periods

Table 3-13. Maximum H_2S Concentrations for Combined Sources at Power Plant and Wellpad E

Case	Rank	Maximum 24-Hour Averages / Maximum 1-Hour H_2S Concentration ($\mu g/m^3$)
Case 1		
Normal Operations (Power Plant and Wellfield Fugitives)	1	6
	2	3
Case 2		
Normal Operations + Well Drilling and Testing	2	76
	2	68
Case 3[1]		
Normal Operation + Well Venting	1	83
	2	78
Case 4		
Emergency Steam Release + Well Drilling and Testing + Wellfield Fugitives	1	107
	2	99

[1]Annual average for Case 3 not applicable because dominated by short period (1 day) events of drilling and venting. Venting limited to daytime periods (neutral or unstable) with windspeeds ≥4 m/s.

Source: Aerometric Monitoring, Inc.

Table 3-14. SAAQS Evaluation for H_2S Maximum Allowable Increment

Pollutant	Averaging Period	2nd Highest Monitored Concentration ($\mu g/m^3$)	2nd Highest Monitored Concentration[b] ($\mu g/m^3$)	Maximum Concentration ($\mu g/m^3$)	Maximum Allowable Increment ($\mu g/m^3$)
H_2S-Normal Operation	1-hour	10	0.1	10.1	35

Notes:

[a]The second highest monitored 1-hour H_2S concentration for normal operation is based on the 1988 H_2S monitoring data excluding data thought to reflect equipment malfunction.

[b]Second highest modeled concentration based on data presented in Table 3-12.

when there were malfunctions of the H_2S abatement system or emergency steam releases at HGP-A. The second highest modeled and monitored concentrations (which occur at different locations)give a conservative estimate for comparison to an increment that, by regulation, may be exceeded once a year at any one location.

Table 3-15 shows that the ambient air quality impact of the proposed PGV Project will be within the allowable increment for H_2S established by the proposed air quality rules.

3.9.2.2.6.NAAQS and Proposed SAAQS Assessment

The air quality impact assessment consists of a comparison of estimated impacts to the National Ambient Air Quality Standards (NAAQS) for particulates and proposed State Ambient Air Quality Standards (SAAQS) for H_2S. For comparison to the NAAQS and the proposed SAAQS the second highest concentration from the ambient air quality monitoring data is added to the second highest value from the modeling results. This method for the NAAQS and SAAQS will result in a conservative estimate because the assumption is made that both the second highest monitored value and second highest modeled impact occur at the same time and location.

The results of the second highest H_2S and particulates monitored values and modeled impacts are given in Table 3-15. The combined concentrations are less than the proposed H_2S SAAQS of 139 $\mu g/m^3$ and less than the 24-hour and annual average SAAQS for TSP and NAAQS for PM_{10}.

3.9.3. Noise

Currently, no noise ordinance with numerical limits is applicable to the site. The County of Hawaii Planning Department has developed Geothermal Noise Level Guidelines from a study of noise in the Puna District (Darby-Ebisu and Associates, Inc., 1981). These guidelines consider 55 dBA during daytime (7:00 a.m. to 7:00 p.m.) and 45 dBA during nighttime (7:00 p.m. to 7:00 a.m.) as satisfactory sound levels for residential areas. The allowable noise limit for impact noise (noise of short duration, typically less than one second, and caused by impacts of pipes, tools, etc.) is 10 dBA higher than the overall daytime and nighttime limits. The allowable noise levels may not be exceeded more than 10 percent of the time in any 20-minute period.

3.9.3.1. Background Noise Monitoring

An environmental noise survey was conducted in early September 1986 at four locations at the PGV site to determine ambient noise levels during weekday periods. Two battery-powered noise monitoring systems were used to measure the ambient noise levels for 24-hour periods at the four locations.

Two of the locations were on residential properties located south and southwest at approximately 0.5 and 1 mile, respectively, from the PGV proposed power plant site. These residence locations were:

- "Brees" Station, lot 54, Lanipuna Gardens, Lauone

- "Gilman" Station, residence, Kaupili Street

The two remaining monitoring locations were on the PGV site, one at Wellpad A and the other at Wellpad B.

Background noise levels during the survey period on and around the PGV site ranged from L_{eq} values of 34.2 dBA (7 p.m. at "Brees" Station) to 53.2 dBA (5 a.m. at "Gilman" Station), which exceeded the County noise guidelines of 45 dBA (see Table 3-16). The relatively high background noise was due to moderate wind (6 mph or greater) and moderate to heavy rain conditions (wind at Hilo averages 7.2 mph year-round and annual rainfall is approximately 120 inches). Early morning rains were observed each day during this survey period and localized rain showers of short duration were observed during daytime hours.

Table 3-16. Range of Background Hourly L_{90} and Average L_{eq} Sound Levels

	On-Site Locations		Off-Site Location	
	Wellpad A (dBA)	Wellpad B (dBA)	Brees Station (dBA)	Gilman Station (dBA)
	Hourly L_{90} Sound Levels			
Daytime	35 to 38	32 to 39	32 to 40	32 to 40
Nighttime	36 to 39	35 to 41	34 to 35	38 to 51
	Hourly Average L_{eq}[a] Sound Levels			
Daytime	37 to 64	35 to 54	34 to 51	39 to 51
Nighttime	38 to 44	39 to 47	36 to 46	41 to 53

[a]Rounded to the nearest dB level.

The prevalent noise during daytime hours is from distant and local traffic, wind, birds, and insects. Noise from operation of the HGP-A facility, located on Pahoa-Pohoiki Road, just south of the PGV site, was barely audible at the PGV onsite monitoring locations (Wellpads A and B) and inaudible at the two off-site resident monitoring stations. (Subsequent experience has shown that the HGP-A facility is, at times, audible at the "Gilman" Station.)

3.9.3.2. Noise Impact Analysis

Development of the geothermal facility will occur in stages. During various stages noise can be expected from the following sources: construction, traffic, well drilling, flow testing and venting, and plant operation.

Construction noise will be caused by power equipment and heavy equipment. Temporary construction noise levels may range up to 89 to 93 dBA at 50 feet. The loudest anticipated noise levels will be backup alarms, which are standard safety features of construction equipment and required to be clearly audible above construction noise. Construction noise will, as much as possible, be restricted to weekday, daylight hours.

The traffic associated with construction of the PGV plant and drilling operations is estimated to be about 35 vehicle round trips per day. Using worst case assumptions of traffic traveling at an average speed of 30 to 40 mph up a grade, the hourly calculated average traffic noise would be between 30 and 40 dBA at a distance of 200 feet from the roadway.

Noise generated during well drilling operations will be temporary. The primary noise sources will be the mud circulation equipment, generators and engines, all of which are located on the drilling rig and are acoustically insulated. Well drilling typically produces noise levels of 64 to 75 dBA at 50 feet. Noise levels from each of the six proposed wellpad locations are predicted to attenuate with distance and reach 45 dBA within 0.6 mi (1 km). Noise levels from drilling at Wellpad E were predicted to range from 46 to 50 dBA at the Kapoho and Pohoiki-Bay Estates residents (see Figure 3-20). The levels at the Lanipuna Garden residences were predicted to range from 46 to 51 dBA from drilling at Wellpad F (see Figure 3-21) and from 45 to 48 dBA from drilling at Wellpad B. All other well drilling noise levels were expected to be less than 45 dBA at the nearest resident receptors. These projections do not consider the sound attenuation of foliage, barriers, and terrain; and PGV has proposed additional mitigation measures, including placing acoustical enclosures around drilling rig engines, to reduce noise levels from drilling (see Section 3.10.5.2).

Remedial well workover operations, which may occur intermittently approximately 5 years from the initial well drilling, will use air as the circulating medium instead of drilling muds. The noise from drilling with aerated water or mud is expected to be higher due to the air compressors. The noise of escaping steam is added to the air compressor noise when steam is encountered. A muffling system will be utilized to reduce steam venting noise to a level 10 dBA above that of the air compressors. It may be possible to further reduce routine steam venting noise levels to that of the air compressors and attempts will be made to do so wherever feasible. Well workovers may last 5 days, but generally not longer unless problems or unusual circumstances occur.

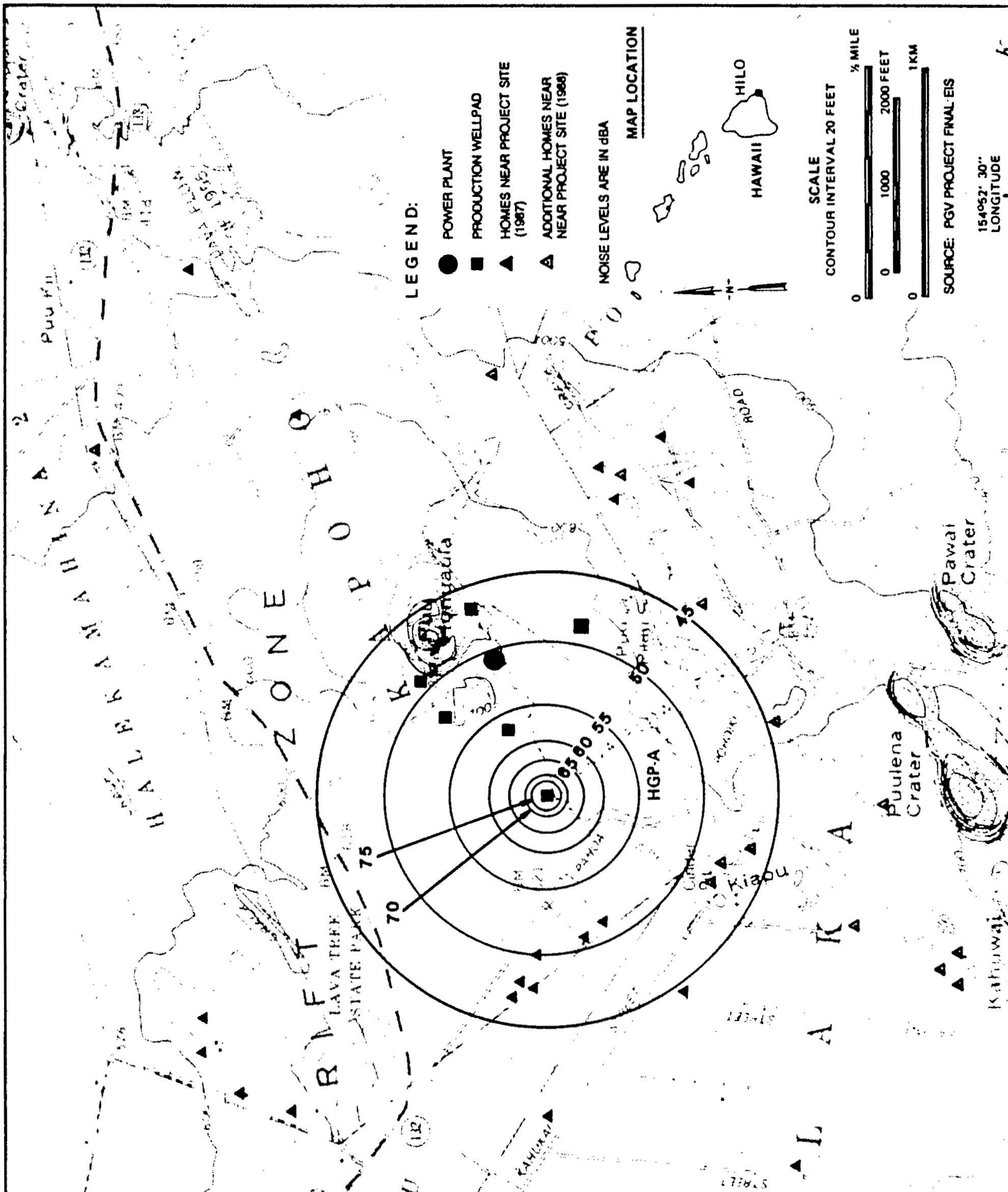


Figure 3-20. Predicted Contours of Well Drilling Noise at Wellpad E

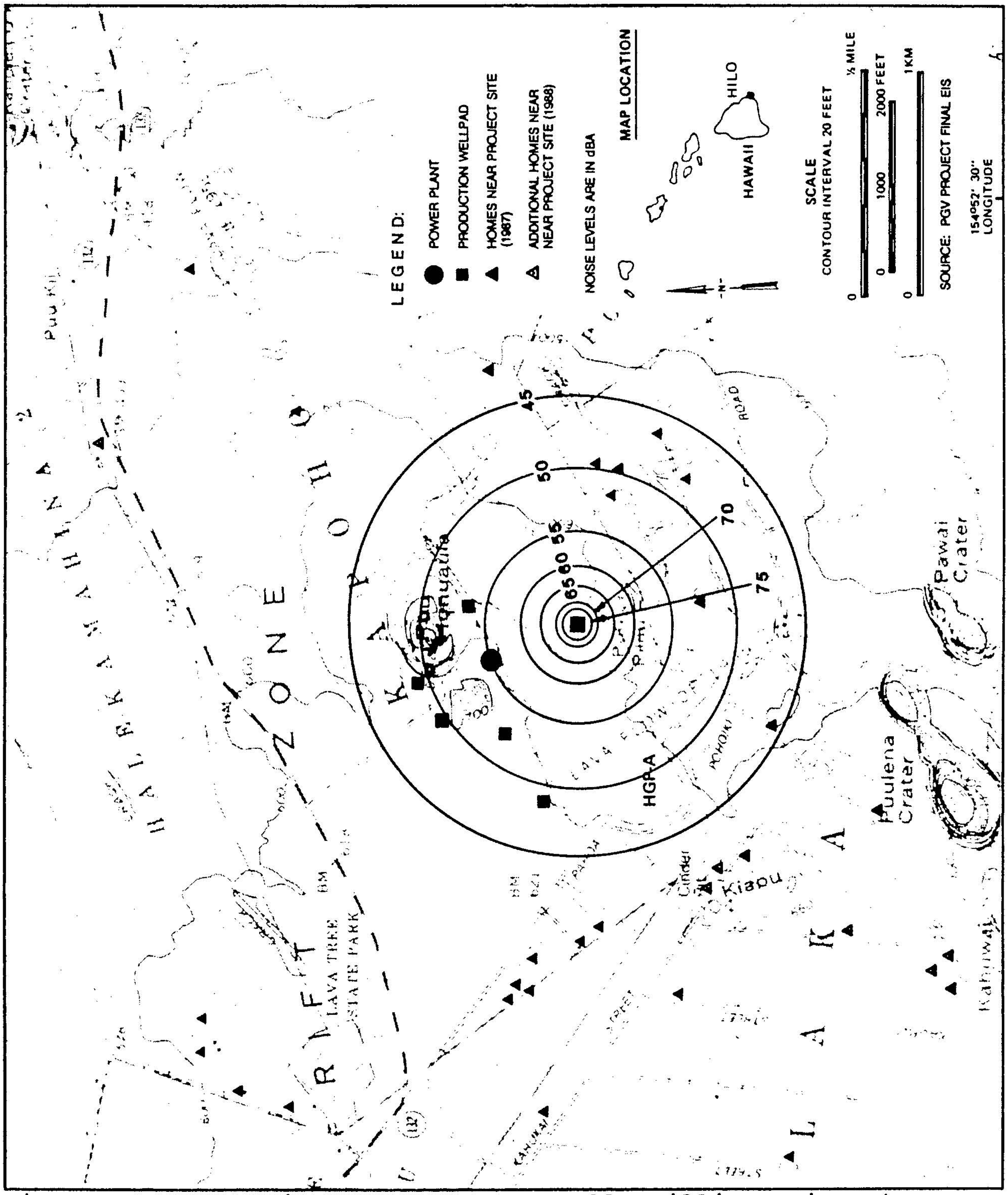


Figure 3-21. Predicted Contours of Well Drilling Noise at Wellpad F

Noise levels from well workover were predicted to increase to 48 dBA at Wellpad A and 54 dBA at Wellpad E for some Kapoho and Pohoiki-Bay Estates residents. The levels at the Lanipuna Garden residences were predicted to increase to 50 dBA from well workover at Wellpad B and 54 dBA at Wellpad F. All other well workover noise levels were expected to be approximately 45 dBA at nearby residences.

Initial, short-term, well venting to cleanout debris may produce noise levels as high as 125 dBA at 50 feet and 50 to 83 dBA at one mile. The wells will be tested to determine capacity and other characteristics after drilling and venting. Testing may initially require up to 10 days; however, it is the objective of the project to reduce this time to 24 to 48 hours of flow as more experience is gained on the wellfield. Testing may be performed continuously or intermittently for the required period. The PGV plant will utilize an effective rock muffler during flow testing to quiet the steam discharge to 55 dBA or less at the lease boundary.

The pipeline gathering system needs to be cleaned and pressure-tested prior to production. This process is referred to as pipeline cleanout and consists of intermittently venting steam from the well at high velocity to an opening in the pipeline where it is released, unmuffled, directly to the atmosphere. PGV will notify nearby communities of pipeline cleanout events. Cleanout normally occurs once for each section of pipeline and normally lasts about one half hour. Noise levels due to pipeline cleanout may be as low as those for steady drilling (75 dBA at 50 feet) or as high as those for unmuffled well venting which can reach 125 dBA at 50 feet, and between 50 to 83 dBA at 1 mile.

Table 3-17 shows the predicted octave band noise levels and resulting dBA values for the major noise sources in the power plant. Based on studies of similar OEC-unit projects, the air-coolers will produce the highest noise levels in the power plant area. The estimated values in Table 3-17 assume that individual steam turbines are enclosed or provided with noise controls of equivalent effectiveness, that appropriate noise control has been applied to the air cooling units and to the H_2S

Table 3-17. Noise Levels Used to Predict Power Plant Noise Emissions

	Sound Pressure Levels in dBA at 50 feet								
Item/Frequency (Hz)	63	125	250	500	1000	2000	4000	8000	dBA
Steam Turbine[a]	69	69	65	63	60	58	53	45	66
Air Cooler, per unit[b]	83	75	73	67	66	64	61	56	72
NCG compressor[c]	65	59	55	69	67	56	46	35	70
Flow noise in steam pipes[d]	51	52	50	51	48	46	43	33	53

[a]Extrapolated from Edison Electric Institute, 1978, with enclosures added.

[b]BBN report at Steamboat Springs, with additional silencing.

[c]Consultants in Engineering Acoustics.

[d]Includes acoustic insulation on steam piping. Not including valves.

Source: Consultants in Engineering Acoustics, 1988 abatement compressors, that some thermal/acoustical lagging has been applied to the piping and valves, as appropriate, and design flow velocities have been selected to avoid distinctive humming in pipelines. Some valve noise levels will exceed levels from piping, but these levels will attenuate to below plant noise levels at the receptors. The total noise power of the ten (10) air coolers will be 10 dBA above that of the individual unit. The combined noise levels from all sources of the proposed configuration is estimated at 83 dBA at 50 feet. These levels are expected to attenuate to 45 dBA within 0.6 mi (1 km) of the site, which is the level identified in the County geothermal noise level guidelines for nighttime noise levels in residential areas (see Figure 3-22).

Measures proposed to mitigate potential noise impacts from the project are discussed in Section 3.10.5.2.

3.10.Environmental Protection

As required by Rule 12.3(b)(2) part (J), this subsection provides "a written description of the measures proposed to be taken for protection of the environment, including, but not limited to, the prevention and/or control of:

(i) Fires.
(ii) Soil erosion.
(iii) Surface and groundwater contamination.
(iv) Damage to fish and wildlife or other natural resources.
(v) Air and noise emissions.
(vi) Hazards to public health and safety.
(vii) Socioeconomic impact(s), and
(viii) Impact(s) on public infrastructure and services."

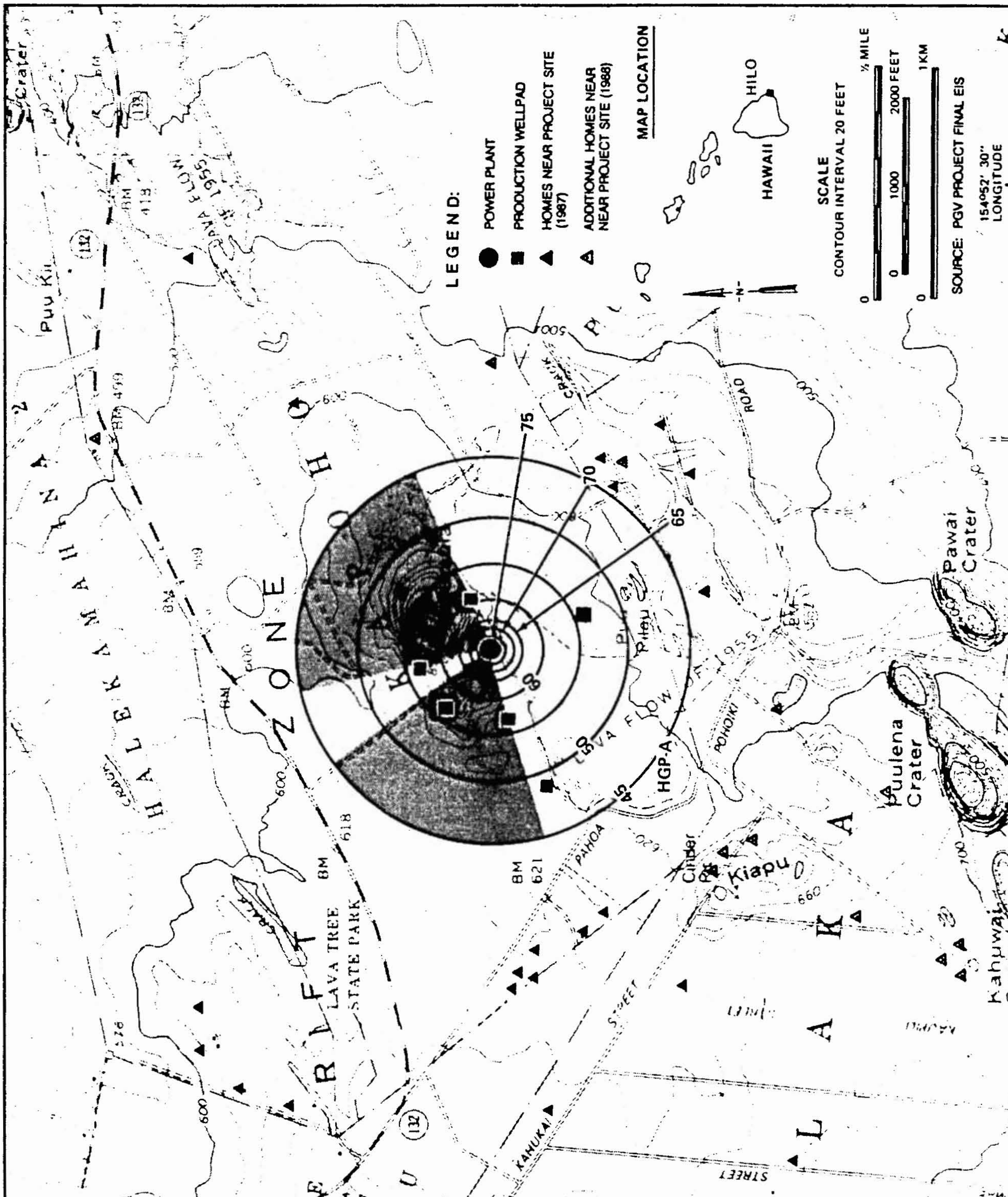


Figure 3-22. Predicted Contours of Noise from Normal Power Plant Operation

3.10.1. Fire Protection

The project will have a complete fire protection system, including a fire water storage tank, hydrants, and pumps. A sprinkler, CO_2 or Halon fire protection system will be installed in the control room, and an electrical fire protection system, and portable fire extinguishers, will be included. The fire protection system is described in more detail in Section 3.2.2.6.3.

Plant operating personnel will be trained in fire fighting techniques and will work closely with the Hawaii County Fire Department (Pahoa Fire Station) and Civil Defense personnel to coordinate emergency services.

3.10.2. Erosion Control

Grading of the relatively flat project areas is not expected to produce erosion problems. Approximately 75 percent of the project area is covered by soils, and these soils (Keaukaha, Opihikao, and Malama series) are classified by the Soil Conservation Service as having only a slight erosion potential. Table 3-18 gives the characteristics of these soils. The southwestern portion of the project area is covered by recent lava flows. The portions of the site covered by bare lava flows have virtually no erosion potential.

Erosion will be controlled by limiting construction vehicles to the areas planned for disturbance and by stabilizing cut and fill slopes according to Uniform Building Code requirements. The regrowth of natural vegetation in the disturbed soil areas will

Table 3-18. Soil Characteristics of Puna Geothermal Project Site

Parameter	Keaukaha Series	Opihikao Series	Malama
Depth	Thin, up to 8 inches	Thick	Thick, up to 12 inches
Description	Very dark brown, mucky, moderate-to-fine sub-angular blocky structure	Upper 3 inches very dark brown, mucky, friable, medium-to-fine subangular blocky structure	Upper 3 inches very dark brown, extremely stony muck
Permeability	High	High	High
Erosion Potential	Slight	Slight	Slight
Underlying Material	Pahoehoe	Pahoehoe	Aa

Source: Puna Geothermal Venture EIS

further stabilize soils.

3.10.3. Protection of Surface Waters and Groundwater

Measures to protect surface waters and groundwater have been incorporated into the project design, although there is no surface water in the project area and the groundwaters are influenced by leakage from the geothermal reservoir. No fresh water exists beneath or downgradient of the project site.

Drilling fluids (a nontoxic mixture of fresh water, clays, biodegradable detergents and special additives to control pH, viscosity, flocculation and foaming) will be discharged to unlined sumps under normal drilling operations. Although the drilling muds will settle to the bottom and form a lining, some liquids will percolate into the groundwater. In addition, some loss of drilling fluid in the subsurface during drilling is expected. Toxicity tests of drilling fluids previously placed in the Wellpad A sump show no EPA-defined toxicity levels. Arsenic, lead and mercury were among the metals analyzed for in these 1985 tests. Neither wellbore fluid losses while drilling or drilling sump residues are expected to approach toxic levels.

Geothermal brines and reacted abatement chemicals (soluble sulfides and hydrosulfides) will be discharged at the test site during well flow testing. The brines and liquids from the rock muffler will percolate into the shallow, geothermally-influenced groundwater. The volume of fluid is small relative to the large volumes of existing groundwater and to the rainfall recharge of the area. Testing of a 90,000 lb/hr well will produce approximately 45 gpm fluids during the 10-day testing period, while recharge from the rainfall on the 500-acre project area averages more than 1800 gpm year round.

As discussed in Section 3.2.3.5, dikes or berms will be constructed around the chemical storage tanks to contain any spills, and federal and state regulations will be followed for the handling and transportation of hazardous materials. Berms will also be constructed around the electrical transformers and the lube oil storage tanks.

All geothermal fluids that are withdrawn from the reservoir will, during normal operations, be injected back into the reservoir well below the shallow groundwater aquifer during normal operations. As required by drilling regulations, both the production and the injection wells will be cased and cemented, which will prevent the geothermal fluids from further mixing with the less saline waters in the upper aquifer. The injection wells will have an additional liner for corrosion control.

The closest sources of groundwater currently providing limited use is near the Kapoho Crater, three miles northeast of the power plant site and the Pahoa station, just less than three miles west of the site. Injection of the geothermal fluids is not expected to affect the waters there because the fluids will be injected below the caprock that seals the upper aquifer from the reservoir. In addition, the dominant dispersion pattern will direct groundwater toward the coast to the south.

3.10.4. Protection of Fish and Wildlife and Other Natural Resources

The biological and other natural resources of the Puna District will be protected by limiting the amount of habitat that will be disturbed by the project to a total of approximately 30 acres of scrub vegetation, fallow fields, and lava flows, five acres of which will only be disturbed temporarily. The project will avoid disturbance to significant biological resources and will control emissions and inject essentially all noncondensable gases and geothermal fluids into the geothermal reservoir.

Biological resources within one mile of the proposed power plant location have been surveyed. The survey recorded 240 plant species in the fallow fields, *Metrosideros* forests, and lava flows within the study area. Figure 3-23 is a vegetation map of the project area prepared by Char and Stemmermann in 1984. The

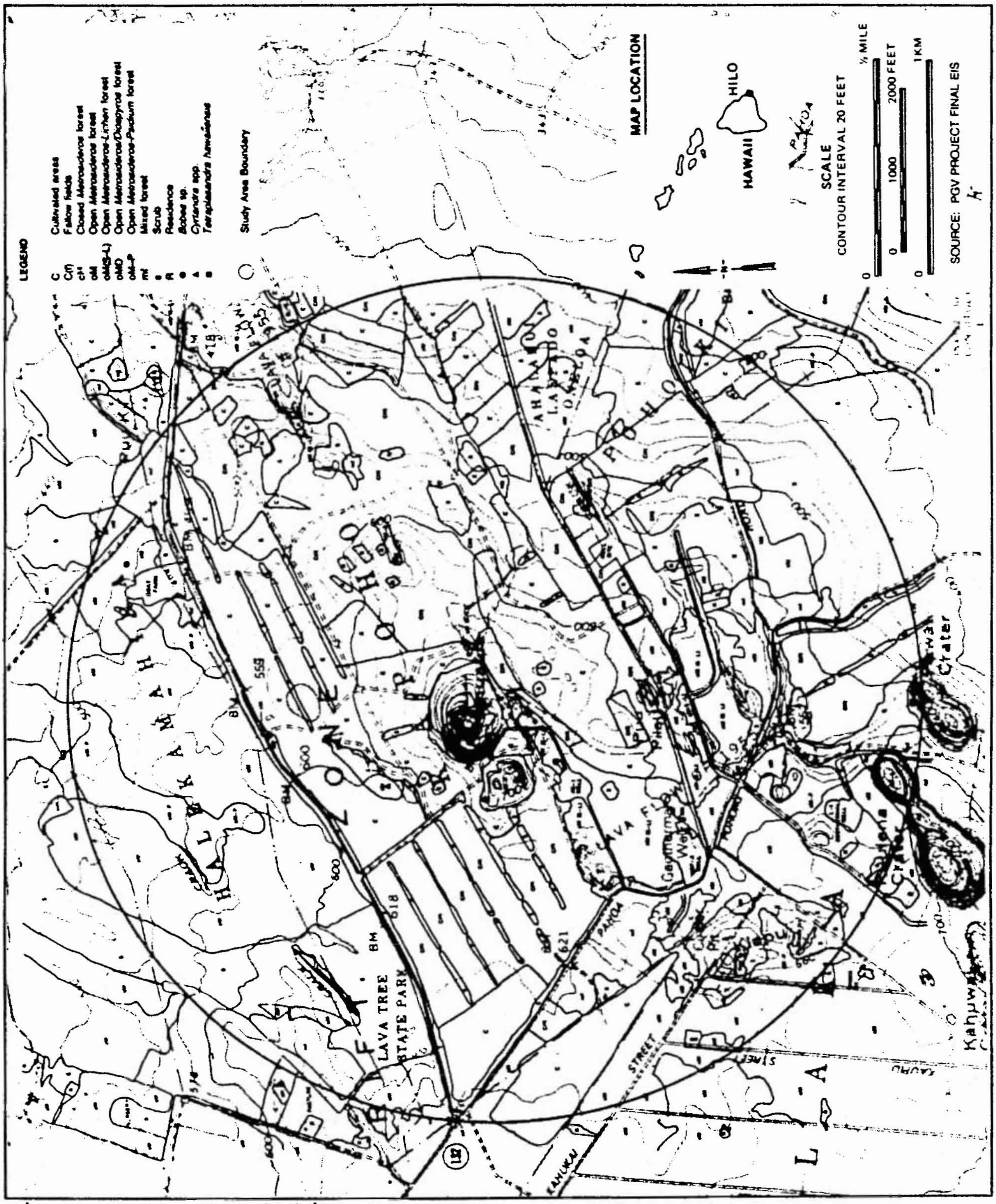


Figure 3-23. Vegetation Map

map shows that most of the areas planned for geothermal development are fallow fields, although Wellpads C and D and the temporary construction area were designated as cultivated in the 1984 survey. The power plant site and access road to Wellpad A will displace lands designated as cultivated and will extend into a portion of the open Metrosideros-Lichen forest.

No rare, endangered, or threatened plant species occur on the power plant or wellpad sites. One candidate endangered plant species (Tetraplasandra hawaiiensis) and three rare species of Cyrtantra and a Bobea species (possibly Bobea timonioides, a candidate endangered species) were identified within the 1-mile area.

Eleven bird species were observed within a 1-mile radius of Puu Honuaula during a 1984 study. Two of the species are native: the Hawaiian hawk and the lesser golden plover. The Hawaiian hawk is on the federal list of endangered species. Its breeding area encompasses most of the Island of Hawaii.

Four field studies of the Hawaiian hawk have been conducted between 1984 and 1986 in connection with the PGV geothermal project. The studies have shown that the hawks use the project area around Puu Honuaula for hunting. No nests have been found on Puu Honuaula. The nearest nest is located about one mile east of the project site.

The activities of the proposed project are not expected to adversely affect the Hawaiian hawk. The hawks are accustomed to human activities in the papaya fields, and use the area primarily for foraging. Even the loudest noises (well venting) will attenuate to 50 to 83 dBA at one mile and are unlikely to affect breeding of the hawk adversely (see Section 3.10.5.2). Under the proposed project design all geothermal wastes, emissions which could be harmful to wildlife will be injected, and the only emissions will be fugitives. Chemical treatment will be applied during well testing and to emergency steam releases to abate H_2S. H_2S emissions during normal operations would be less than 0.1 lb/hr, which would result in ambient levels well below injury level to sensitive plant and animal species.

3.10.5.Control of Air and Noise Emissions

As described in Section 3.2, procedures and techniques have been incorporated into the design of the PGV Project to control air and noise emissions during each stage of the project: site and pad construction, drilling, well testing, normal power plant operation, and emergency steam release during outages (steam stacking).

3.10.5.1.Control of Air Emissions

The following measures are proposed to protect the environment and public from potentially harmful air emissions from the PGV Project. These potential emissions include H_2S, particulate and trace elements in the steam; fugitive emissions of isopentane; criteria pollutants in the exhaust from construction and drilling equipment; and fugitive dust.

- During construction, conduct regular maintenance of construction equipment and drilling rig engines to prevent undue discharges of criteria pollutants (carbon monoxide, hydrocarbons, nitrogen oxides, sulfur dioxide, and total suspended particulate). Criteria pollutant emissions from these engines will not exceed the significant levels defined in the Hawaii Air Pollution Control Rules (Chapter 60, Title 11).

- Control fugitive dust from construction operations by sprinkling exposed soil in the construction area with water, as necessary.

- Install blowout prevention equipment (BOP) at each wellhead to prevent uncontrolled releases of geothermal steam at the wellhead.

- Employ mud drilling techniques to reduce H_2S emissions from most drilling operations to negligible levels. Inadvertent H_2S emissions during drilling with aerated water or mud will be less than 7.0 lb in ten minutes. Inadvertent releases of steam will be stopped (using BOP equipment if necessary) if they exceed 10 minutes.

- Vent the drilling fluids through a cyclone separator to control particulates during drilling.

- Ensure the integrity of the geothermal wells by designing wells and wellheads with conservative safety factors.

- Use conservative safety factors for design of process facilities and the related piping to prevent uncontrolled releases of air contaminants into the atmosphere.

- Limit time of well venting and cleanout (to approximately four hours duration) per well as much as possible and perform these operations only during proper meteorological conditions (winds ≥ 4 m/s) and with proper notification.

- Abate well testing emissions by (up to 95 percent) by routing the flow through the rock muffler at the wellpad and injecting water and NaOH, as needed.

- Use an H_2S abatement system which injects essentially all noncondensable gas back into the geothermal reservoir. This gas injection system has been demonstrated effective at the Coso geothermal field in California.

- Use air-cooled OEC units in place of water-cooled condensers and cooling towers to produce a closed-loop system that eliminates all but minor fugitive release of geothermal gases to the atmosphere.

- Design the injection system with spares for all major systems, including a spare pump, a spare compressor, and a spare injection well.

- Periodically inspect piping connections and welds to reduce fugitive emissions of H_2S and isopentane. Monitor pressure levels in working fluid cycle.

- Design the process plant equipment with automatic instrumentation and controls to minimize the possibility of a rupture disk event resulting from a process upset. Set rock muffler release valve at a lower trigger point than the rupture disk, so as to route overpressure steam to the abatement system in the mufflers.

- Use NaOH injection at the power plant rock muffler to control H_2S emissions by 96 percent during steam operations (state-of-the-art rock muffler design).

- Minimize the emissions from emergency steam releases by designing both steam turbine/OEC units with high reliability factors.

With these control measures, the total emission of H_2S will be less than 10 tons/year, which is the significance level for H_2S in the Department of Health (DOH) regulations. The proposed measures also meet the requirement of the DOH regulations which cover geothermal power plants and wells.

3.10.5.2.Control of Noise Levels

The following mitigation measures are proposed to mitigate potential noise impacts from the project. The most significant noise levels will be generated during short-term operations such as well venting, flow testing, and pipeline cleanout.

- Set construction equipment backup alarms at minimum legal limits.

- Reduce drill rig noise by using residential-grade mufflers, placing an acoustic enclosure around drill rig engines and other noisy mechanisms, and silencing engine radiator air inlets and outlets.

- Use silencers and/or enclosures on auxiliary equipment used during well drilling and workover operations (diesel generators, pumps, compressors, etc.).

- Employ steam vent muffling system when steam is encountered during well workover operations.

- Use rock mufflers to control noise during flow testing operations and emergency steam releases.

- Schedule especially noisy short-term operations, such as well venting and pipeline cleanout, for daylight hours only and notify the public prior to such operations.

- Acoustically insulate selected pipes and valves.

- Connect pressurized steam outlets to condensate piping and/or rock mufflers, where possible.

- Muffle or enclose individual steam turbine generators, or provide an equivalent level of noise control.

- Provide acoustic insulation, sound barriers, acoustically improved fan design, or other noise controls, as needed, on the air-cooled condensers.

- Schedule noisy maintenance activities for daylight hours only.

3.10.6. Protection of Public Health and Safety

The measures taken to control air emissions, reduce noise levels, and contain water effluents will also serve to protect public health and safety. The risks to public health and safety consist primarily of exposure to H_2S. The geothermal resource at Puna has higher H_2S concentrations and lower arsenic, boron, mercury, and radon-222 concentrations than other geothermal resources developed on the mainland (Geysers, Imperial Valley, Coso, Nevada, and Utah). The proposed design with its closed-loop configuration of steam turbines/air-cooled OEC binary units and gas injection system will minimize public exposure to H_2S and the other elements in the geothermal fluids. The geothermal fluids and gases will be isolated from the atmosphere and will only be released as fugitives or in the event failure of multiple units in this configuration. The maximum predicted ambient levels of H_2S are below the proposed State of Hawaii standard of 0.10 ppmv, which is set 100 times lower than the occupational standard.

Other potential health and safety concerns are exposure to elevated noise levels (occupational exposure), construction accidents with heavy equipment, exposure to hazardous chemicals, traffic accidents, well blowouts, and pipeline ruptures. The potential risks associated with these hazards are comparable to and, in some cases, less than other industrial projects.

In addition to the measures taken to control air emissions (see Section 3.10.5.1), the following design measures are proposed to protect public health and safety.

- Design wellfield program to prevent blowouts (see Section 3.2.1.3 and Appendix B for details on blowout prevention equipment).

- Design pipelines in accordance with applicable ANSI and Hawaii State pipeline safety requirements.

- Implement noise suppression measures in all phases of project design and operation (see Section 3.10.5.2).

- Secure the project area with a chain link fence around wellpads and power plant site and limit public access.

- Require training of personnel in the areas of safety and emergency procedures, such as the proper shutdown of well equipment during an emergency.

- Employ hand-held H_2S monitors for employees throughout the plant during well venting, flow testing, pipeline cleanout and maintenance activities in confined space to promptly detect any H_2S exposure. Install H_2S alarms in noncondensable gas compression areas and other areas where H_2S may accumulate.

- Adhere strictly to applicable hazardous materials storage and transportation regulations. Inform all employees of the hazards of each compound and the appropriate emergency procedures in the event of an accidental contamination.

- Schedule deliveries and truck traffic to avoid peak traffic periods and install turnout lanes on the main access road.

- Work with Civil Defense in the development of the emergency response plans.

3.10.7. Prevention of Adverse Socioeconomic Impacts

The development of the PGV facility will result in a number of positive economic and social impacts. These impacts include jobs for local residents, increased economic activity from capital expenditures in the county, increased state and county revenues from taxes, royalties, and permit fees, and increased energy self-sufficiency.

The PGV Geothermal Project will provide both the State and the Island of Hawaii with a number of beneficial aspects and assists in meeting a number of goals. The project is anticipated to:

- Decrease dependence upon imported petroleum products.

- Diversify Hawaii's economic base.

- Provide increased employment opportunities and personal income.

- Increase public revenues and capital expenditures.

- Provide a dependable and efficient source of energy.

- Develop an alternate, renewable energy source which is indigenous to the Island.

- Further the State program to develop additional information on the commercialization of geothermal energy.

The Puna District, with a 1984 population of 16,530, is the third most populous of the Island Of Hawaii's nine districts. During the 1970s the Puna District experienced a 128 percent population growth which shifted the ethnic composition of the area from largely Japanese to largely Caucasian. During the same period, the proportion of Puna's population consisting of native Hawaiians increased from 9 percent to 15 percent. Many of the immigrants to the area were from the mainland, either retirees or participants in subsistence economies, and were attracted to the area because of its isolated, natural environment.

Although the economy of the island as a whole has shifted from agriculture to tourism over the past several decades, the economy of the Puna district is largely unaffected by tourism. A 1982 survey of 778 Puna households showed that 31 percent were retired or not working, 20 percent working in agriculture, 12 percent in construction, 8 percent in government, and 1 percent in the geothermal industry. Puna has been a major sugar producing area, but production has stopped since the Puna Sugar Company ceased operations in 1984. The median family income in lower Puna where the project is located is 72 percent of the island-wide level, and the area has a higher proportion of families qualifying for poverty status than the rest of the island.

The housing supply in Puna increased by 79 percent in the 1970s, with most new housing stock generated through custom home construction in land subdivisions. The median value of owner-occupied housing in Puna is significantly lower than for the island as a whole.

Most of the positive socioeconomic impacts are associated with the direct and indirect effects of the estimated 23 construction and 19 operations and maintenance jobs at the proposed project that will be filled by local employees. Peak construction employment is estimated to be as high as 100 people. Construction of the project will generate a total annual increase in personal income of more than $16 million, and that annual operation will produce another $1.8 million. The proposed project will also increase county revenues through property taxes, permit fees, and other fees collected through increased economic activity.

Additional employment may be generated by potential spin-off activity such as use of geothermal heat for papaya drying or industry attracted to other areas of the island by the existence of reliable electrical energy. Spin-off activities are not an automatic consequence of the proposed action, and future industries would have to be permitted on a case-by-case basis. The socioeconomic effects of the project were perceived as positive by most of the region's population but some perceived the project as disruptive to the traditional rural atmosphere. Surveys indicate support of two-thirds of the population for geothermal development on the scale of the proposed project. About 17 percent of respondents opposed the project. This opposition may decline if the proposed project operates as unobtrusively as planned.

The measures proposed to avoid adverse socioeconomic effects are the same as those designed to protect the other aspects of the environment: control of air emissions, noise levels, and other impacts so that they will not intrude upon the rural environment outside the project boundaries. Additionally, state and county government planners can help allay community fears about the PGV Project by providing local forums for discussion of geothermal development.

The only potential adverse socioeconomic impacts of the project will be visual. Visual analysis indicates most views of the project area will be screened by existing vegetation or by Puu Honuaula. The project will be visible from portions of Highway 137, Pahoa-Pohoiki Road, and Leilani Avenue; however, these views will be from at least 0.5 miles distance, and visibility impacts will be mitigated by the measures described in Sections 3.3.1 and 3.3.2.

3.10.8. Prevention of Adverse Impacts on Infrastructure and Services

3.10.8.1. Traffic

Traffic through Pahoa will increase slightly during construction of the project. Approximately 35 vehicle round trips per day are expected during the wellfield and power plant construction. Traffic during normal power plant operation will drop to about 10 to 18 vehicle trips per day. These added vehicle trips amount to a less than a one percent increase over existing traffic levels at the intersection of Highways 130 and 132, based upon the existing traffic levels of 2000 to 3600 vehicles per day at this intersection. The increase should not cause a significant impact on traffic in the project area.

PGV plans to use Kapoho Road (Highway 132) rather than the existing access road (Pahoa-Pohoiki Road) as the primary access to the site because it has fewer curves. An entrance road will be constructed to the project site. A right-turn lane from Kapoho Road into the project area will be provided for traffic coming from the west. This right-turn lane will reduce traffic congestion associated with vehicles (especially construction-related vehicles) turning into the project site.

3.10.8.2. Utilities

Telephone service is provided by the Hawaii Telephone Company and expansion is provided as demand requires. During construction, electrical power will be provided by HELCO. A 34.5 kV overhead electrical transmission line currently extends along the Pahoa-Pohoiki road to the HGP-A Site to share poles with the telephone system.

During operation, onsite power requirements will normally be met using power generated by the plant itself. A diesel generator unit will be available as an emergency backup if the system power fails (see Section 3.2.2.4).

3.10.8.3. Water Supply and Distribution

The public water supply and distribution system is operated and maintained by the County Department of Water Supply. There are four major public water systems in the Puna District, one of which has been extended beyond the HGP-A project site from a well located above Pahoa. A water line supplies potable water from the county water main.

Up to 30,000 gallons of water per day will be needed during the drilling for makeup to replace lost circulation fluids. PGV plans to purchase this water from the county unless it develops its own water supply. For supplemental injection water needs see Section 3.2.2.6.4.

Service water requirements for the PGV facility are estimated at approximately 1000 gallons per day from the public water system. Service water is required for drinking water, sanitation, occupational safety (i.e., emergency showers and eyewash stations), and chemical mixing and makeup water.

For general plant purposes, there will be a separate system utilizing condensate water. If additional water is needed, rain catchment water, piped-in County water, and trucked-in water can be used.

Initial filling of the fire water tank will be from the county water system. Make-up will be from the condensate system.

3.10.8.4.Sewage Disposal System

There will be no impact on public sewage facilities from the PGV Project. It is estimated that the proposed project would generate an average of less than 200 gallons of domestic wastewater per day. Current plans are to dispose of domestic wastewater at onsite in cesspools. These cesspools are expected to perform satisfactorily due to the highly porous nature of the soils and underlying rock and their successful usage elsewhere in Puna. Portable toilets may also be used during peak periods. No public drinking water sources would be affected by this disposal system.

3.10.8.5. Fire Protection

The PGV Project will have its own fire protection system (see Sections 3.2.2.6.3 and 3.10.1), and will place minimal demands on the Hawaii County Fire Department (Pahoe Fire Station).

3.11. Reconciliation of Public Impacts

This subsection provides "statement(s) addressing how the proposed development would mitigate or reconcile: i) Any effects to residents or surrounding properties in the areas of health, environment and socioeconomic activities; and ii) The burdening of public agencies to provide support infrastructure such as roads, sewers, water drainage, school and related services and police and fire protection" as required by Rule 12.3(b)(2) part (K).

The PGV Project has proposed a number of measures to protect the environment from fires, soil erosion, surface and groundwater contamination, damage to fish and wildlife and other natural resources, air and noise emissions, hazards to public health and safety, socioeconomic impacts, and impacts on public infrastructure and services. These measures are described in detail in Section 3.10. With these environmental protection measures in place, no adverse impacts are expected to residents or surrounding properties in the areas of health, environment, and socioeconomic activities, and the project is not expected to burden public agencies providing infrastructure and other services.

The nearest residents are more than 2,000 feet from the power plant site in Lanipuna Gardens and more than 3,400 feet from the site in Leilani Estates. Six residences are within a half-mile of the site; another 24 within a mile. The proposed project will occupy about 5 percent of the 500 acres leased by the project. The remaining acreage will provide a buffer zone between the project and the residences. The presence of residential development relatively close to the site has prompted the PGV Project to employ the most effective measures to control air and noise emissions.

With the proposed project design, the geothermal fluids, which contain H_2S, will not come in contact with the atmosphere during normal operation. During some outages, steam will be released through the rock mufflers, but this steam will be treated with state-of-the-art abatement systems to control emissions by 96 percent. At this level of control, the ambient concentrations of H_2S in the residential areas will be well below the levels known to cause health effects.

A study of the impact of the HGP-A facility on housing values in the vicinity of the site found that the odor of H_2S emissions from the HGP-A facility could decrease housing values of residences within 0.5 miles of the power plant site by as much as 50 to 70 percent. The proposed project, with much more effective H_2S control technologies than HGP-A, is not expected to produce this kind of decrease in housing values.

Similarly, the noise levels will be reduced so that the attenuated levels at the nearest residences will be lower than those levels specified in the guidelines developed by the County of Hawaii Planning Department. Noise from the existing HGP-A Project was not audible during the site surveys. PGV will monitor noise levels and ambient concentrations of H_2S, to verify the predicted impacts of the proposed project (see Section 3.12). This monitoring program will also provide reassurance to the community that there are no adverse health or environmental effects.

The implementation of effective environmental controls is expected to preclude any adverse socioeconomic effects on the surrounding residences. Without unpleasant odors or noise levels and with proper vegetative screening and a sufficient buffer zone between the project and the residential areas, there is no physical basis for the project affecting property values.

Despite these measures, some unanticipated effects may occur or residents may feel that additional mitigation is required to offset unanticipated project effects. PGV has participated in a number of local community groups, which are intended to provide a forum for resolution of issues and discussion of measures to reconcile public impacts. Some of these political and community groups include:

Puna Community Council
Leilani Community Association
Nanawale Community Association
Mayor's Geothermal Advisory Commission
Big Island Business Council
Hawaii Island Economic Development Board
Hawaii Island Chamber of Commerce

PGV will continue to work with these organizations and with the Planning Commission and Department to develop additional measures, if needed, to mitigate or reconcile public impacts.

Similarly, the project will have its own roads, sewage system, water collection system, fire protection system, and drainage systems, although it will use water from the Pahoa District (see Section 3.10.8). These systems will prevent adverse impacts on public agencies providing infrastructure support in areas such as roads, sewers, water, drainage, related services and police and fire protection. If unanticipated effects occur during the construction or operation of the project, PGV will work directly with the affected agency and the Planning Department to develop measures to relieve the unforseen burden on local agencies.

3.12.Monitoring Plans

This subsection explains "preliminary provisions and/or plans for the monitoring of environmental effects such as noise and air and water quality during each proposed phase of the project (exploration, development and production) demonstrating how the applicant intends to comply with this rule, the rules of the State's Department of Health, and the rules of the State Board of Land and Natural Resources" as required by Rule 12.3(b)(2) part (L).

3.12.1.Meteorological and Air Quality Monitoring

The meteorological monitoring stations at the "Woods" Site and at the plant site will be kept in continuous operation, and additional meteorological and air quality monitoring will be performed to ensure that all design and environmental criteria are met. Meteorological monitoring at the "Woods" Site include wind speed, wind direction, wind direction fluctuation (sigma theta), temperature, relative humidity, rainfall, and solar radiation. Meteorological monitoring at the plant site includes wind speed, wind direction, temperature, relative humidity, and rainfall.

Continuous ambient measurements of H_2S will likely be conducted at three sites: "Schroeder", "Gilman", and a new site located near the residences on Kaipu. H_2S levels will be monitored throughout the construction, operation, and decommissioning phases of the project. During well drilling and plant operations, the air will be monitored in strategic locations. Permanent H_2S monitors and emergency air units will be located in strategic places. Hand-held H_2S monitors will also be used extensively throughout the plant for detection of H_2S exposures in those areas not having permanent detectors, especially in confined spaces.

Because the proposed PGV Project design eliminates the cooling tower and the cooling tower drift, which was identified as the primary source of arsenic from the previously proposed PGV Project, PGV does not plan to conduct the previously proposed arsenic monitoring studies. All of the arsenic, radon, mercury, lead, and other trace elements in the geothermal fluids will be contained in the brine, condensate, and gases that will be injected back into the geothermal reservoir. There will be no occupational exposure to these elements during normal operation of the project, and the only occasions for exposure will be the infrequent periods of emergency steam release and well testing and turbine maintenance. Brief periods of exposure to low concentrations of these elements do not require occupational monitoring studies. Similarly, there will be no radon releases from the proposed design, and PGV does not plan to monitor ambient levels of radon near the site.

3.12.2. Noise Monitoring

PGV will perform a 24-hour noise monitoring survey after start-up of the power plant to verify the noise specifications of equipment and a noise survey to ascertain the impacts of operational L_{90} and L_{eq} noise levels on residential areas and compliance with County guidelines. Noise monitoring will also be conducted if requested by the Planning Department in response to public complaints. Public notification will be provided for one-time events which may cause high noise impacts, such as well venting or pipeline cleanout.

3.12.3. Biological Monitoring

PGV does not intend to continue biological monitoring of the Hawaiian hawk, because changes in the project design eliminate the major source of regular emissions, and, consequently, the potential for impacts on the Hawaiian hawk and any rare native plants from cooling tower emissions is eliminated. Although the noise impacts will be similar to those described, no adverse impacts on the Hawaiian hawk are anticipated from even the loudest noise produced by the PGV facility.

3.12.4. Compliance with Regulations

The planned monitoring will assure that the project is in compliance with the following regulations:

- County of Hawaii Planning Commission's Rule 12 (Geothermal Resource Permits).

- DOH's Ambient Air Quality Standards (Title 11, Chapter 59), Air Pollution Control regulations (Title 11, Chapter 60), and Underground Injection Control regulations (Title 11, Chapter 23).

- DLNR Geothermal Plan of Operation rules (Title 13, Chapter 183, Subchapter 7), Well Drilling rules (Title 13, Chapter 183, Subchapter 8), Well Modification for Injection requirements (Title 13, Chapter 183, Subchapters 8 and 9), and Well Abandonment regulations (Title 13, Chapter 183, Subchapters 8 and 11).

Necessary permits will be obtained from the authorizing governmental agency. Permit applications will detail how the PGV operations will comply with the applicable requirements.

3.13. Emergency Preparedness Plans

This subsection provides "a preliminary plan of action for emergency situations which may threaten the health, safety, and welfare of employees and other persons in the vicinity of the proposed project site including, but not limited to, procedures to facilitate coordination with appropriate Federal, State and County officials and the evacuation of affected individuals," as required by Rule 12.3(b)(2) part (M).

The PGV Project submitted an emergency preparedness plan for well drilling and testing of the existing wells and a plan to cover the current period when the wells are closed down (shut in) and unattended. These plans have been approved by the County Civil Defense Director and are in effect. Prior to the beginning of construction, these emergency preparedness plans will be combined and expanded to cover the construction and operational phase of the project. An outline of the information recommended for the construction and operational phase is presented in Appendix D. During operation the emergency preparedness plan will be reviewed annually and updated to reflect current contact telephone numbers and safety requirements.

The plan will describe the proposed facility and its operation, identifying areas of potential hazard such as storage of flammable materials (lube oil, isopentane), presence of potentially hazardous substances (H_2S and NaOH), and high-pressure piping. The plan will describe coordination agreements with outside agencies and define the division of responsibility expected between the agencies and the project. Onsite chains of command and levels of responsibility in emergency situations will be included in the emergency preparedness plan.

The operation plan will be divided into subsections according to the potential hazards (well blowout, chemical spills, H_2S hazards, pipeline rupture, fires, contaminated soils, etc.). For each subsection, the plan will identify technical data on the nature of the hazards (for example, the concentrations of H_2S in the various areas and the hazard associated with these concentrations, the corrosive characteristics of the abatement chemicals) and describe the warning systems (such as H_2S detectors used to alert personnel of the hazard). Each subsection will also define the location and use of equipment used to control the hazard (fire protection equipment, isolation valves). It will identify the personnel trained in the use of that equipment and define the authorities which must be notified if the hazard occurs. Additional subsections will deal with natural hazards such as lava flows, earthquakes, and storms, and identify coordination agreements and expected warning times. A summary checklist will be provided that identifies the emergency, describes control options, and defines when to evacuate and when to notify outside services and agencies.

The plan will identify the location and capabilities of available medical facilities and will describe plans for transporting injured personnel. Evacuation plans and alternate routes, including meeting points, will be included in the plan. The plan will identify those situations requiring media and/or public notification and list personnel authorized to make statements to the media and/or the public.

Training requirements will be included in the plan, including procedures for emergency shutdown, handling of emergency equipment, spill prevention, first air and rescue, fire fighting procedures, and evacuation training. The plan will also include reporting and recordkeeping requirements.

3.14. Schedule

This subsection provides a "preliminary timetable(s) and/or schedule(s) for each proposed phase of the project" as required by Rule 12.3(b)(2) part (N).

The current development schedule for the PGV Project calls for the commencement of the development of the geothermal wellfield and the construction of the power plant as soon as all the necessary permits are obtained and the contract with HELCO is finalized. Accordingly, PGV assumes that the wellfield development and construction of the power plant will start during the second half of 1989. The wellfield development and the power plant construction will continue uninterrupted through to the end of 1990, when commercial operation of the full 25 MW project is scheduled to commence (see Figure 3-24). Permit acquisition and project engineering are both currently in progress, and equipment fabrication is scheduled to begin by mid-1989, as soon as all the permits are obtained and the contract with HELCO is finalized.

The final timing of commercial operations will depend, in part, on the results of the capacity contract and transmission line negotiations now being concluded between PGV and HELCO, and the completion of the permitting process. However, the current schedule anticipates that commercial operations will commenced in stages, as requested by HELCO, which is made possible by the modular nature of the power plant design. As currently envisioned, the schedule calls for the first phase of the project, generating 7.5 MW, to be ready by early 1990. At this phase, all the power generating units will be OEC binary units, which can be manufactured in a shorter time than the steam turbines. The second phase, generating up to 20 MW, will consist of all the OEC units and, if available, a few steam turbines. The final phase of the project, generating the total 25 MW (net), would commence commercial operation by the end of 1990. Depending on the transmission line and contract negotiations with HELCO and the date that all permits are obtained, a possible alternative schedule divides the project into only two phases; 12.5 MW by mid-1990, and completion to 25 MW by the end of 1990. In any case, the drilling of the wells and construction of the power plant is scheduled to start as soon as possible and will continue uninterrupted through to the end of 1990 when full commercial operation commences.

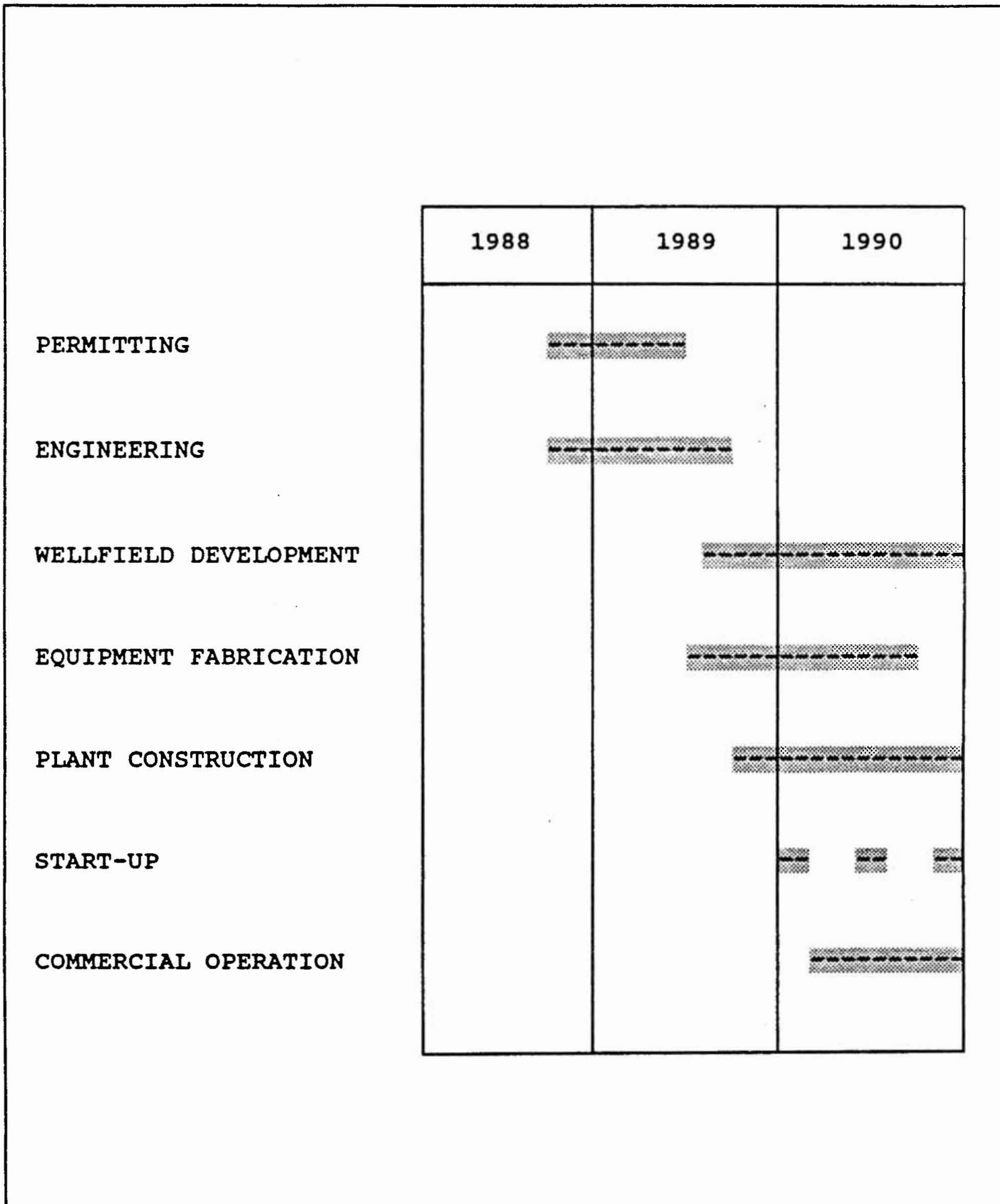


Figure 3-24. Generalized Project Schedule

The operational life of the facility is estimated to be 35 years, after which the plant and wellfield will be decommissioned (see Section 3.2.7).

3.15. Progress Reports

This subsection includes a discussion "method(s) of presenting timely progress reports to the Planning Commission" as required by Rule 12.3(b)(2) part (O).

Written progress reports will be submitted to the Planning Commission as required.

3.16. Cultural Resources

This subsection includes "other pertinent information or data such as an archaeological survey which the Planning Director may require to support the application for the utilization of geothermal resources and the protection of the environment," as Required by Rule 12.3(b)(2) part (P).

The PGV Project should not impact on the cultural and historical resources of the Puna area. The district did not play an important political role in the history of the island and was typically controlled by chiefs of the adjacent districts, Hilo or Kau. The district was a traditional religious center with some of the first heiau, places of worship, built in the Kapoho area, several miles from the site. Most of the archaeological sites in the area have been at Kapoho or on the coast.

At the request of PGV, the Department of Anthropology of the Bernice Pauahi Bishop Museum performed an archeological reconnaissance survey of specified lands (Tax Map Key 1-4-01:1, 1-4-01:2, and 1-4-01:19) in the Kapoho area in January 1984. The purpose of the survey was to determine the presence or absence and general nature of any archeological resources evident on the surface of the project area. A copy of the study can be reviewed by the public at the Historic Sites Section of the Department of Land and Natural Resources (DLNR). The DLNR reviewed the study and concluded that the project will not have an effect on historic sites.

The survey included a systematic walk-through of the site area. The area within a 1-mile radius of the immediate survey area was also investigated on a less intensive basis. No archeological sites were located during the reconnaissance survey.

No further archeological work is planned prior to development because of the lack of surface remains and the highly unlikely event that subsurface remains will be encountered during the construction phase of this project. However, if construction activities expose any cultural remains, PGV will consult with the State Historic Preservation Office, and a qualified archeologist will be contracted to monitor further work and implement appropriate mitigation procedures.

The proposed geothermal wells and power plant are located in Kilauea Volcano's East Rift Zone, part of Pele's traditional home. Some worshippers of the goddess Pele believe that withdrawing steam from the volcano would desecrate her body. Consequently, an appeal was filed on decisions by the State Board of Land and Natural Resources (BLNR) to allow geothermal development in approximately 9,000 acres of the Wao Kele O Puna forest area, about 8 miles up-rift from the project site. The challenge was brought on the grounds that the development would interfere with the plaintiff's constitutional rights to practice their religion (Pele worship). However, the Hawaii Supreme Court subsequently ruled that the plaintiffs had not shown that geothermal development would infringe on their religious practices. The Court therefore denied the appeal and upheld the BLNR decision allowing geothermal development. Subsequently, the Pele Defense Fund asked the U.S. Supreme Court to consider the same case, but the Court returned the request without comment, indicating it would not hear the case and letting the state court ruling stand.

Although some native Hawaiians have opposed geothermal development on religious grounds, other Hawaiians have accepted it and found the use of geothermal energy consistent with traditional approaches to the utilization of natural resources. The proposed closed binary cycle, which returns all geothermal fluids to the reservoir, is more in keeping with Pele's admonition not to remove rocks and volcanic material from Hawaii. PGV respects Hawaiian religious beliefs, and its operations will not interfere with local religious practices. Hawaii religious figures have previously blessed the drilling of wells and the installation of major pieces of equipment at Puna, and PGV plans to continue this practice.